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BACTERIAL WARFARE[1]

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BACTERIAL warfare is one of the recent scare-heads that we are being served by the pseudo-scientists who contribute to the flaming pages of the Sunday annexes syndicated over the nation's press. This question of bacterial warfare has been brought forward from time to time since World War I. The use of the organisms that cause communicable diseases as an instrument of warfare was considered by the Conference on the Limitation of Armaments held in Washington in 1922. An international commission consisting of Professors Pfeiffer (Breslau), Bordet (Pasteur Institute), Madsen (Copenhagen) and Cannon (Harvard), appointed at the time, reported to the League of Nations essentially as follows: (a) The effects of bacterial injury can not be limited or localized; (b) modern water purification methods protect against the organisms of typhoid and cholera; (c) plague is a disease that would be as dangerous for the force using the organisms as for the attacked; (d) the danger from typhus has been exaggerated; (e) modern sanitary methods are effective in controlling communicable diseases.

Following this pronouncement by these eminent scientists, the question of bacterial warfare suffered a lapse of interest; but during the past year, as an incident of the preparation for the Geneva Convention, there has been a marked revival of interest in this supposed bugbear, bacterial warfare. Possibly this is only a part of the effort of professional pacifists to add all the imaginary frightfulness they can picture to the known real horrors of war.

The space and thought that have been given to this question by feature writers have not been without effect and many people now believe that bacterial warfare represents a real threat and problem for future generations. Many are now associating chemical warfare and bacterial warfare, with the result that in the resolution of adjournment, voted by the General Commission of the Disarmament Conference on July 23, 1932, at Geneva, we find chemical, bacteriological and incendiary warfare grouped for consideration. The mere fact that this great body of peace workers considers bacterial warfare seriously enough to prohibit its use justifies military men in considering this agency of warfare. We know how little treaties protect, so we should study the question to see if the use of biologic weapons is a real problem for the military minds of the future.

Under biologics we include all those

[1] This article was written nearly ten years ago and appeared in military journals in several countries, and it will be reprinted in *The Military Surgeon* in the near future. The subject is timely and of much scientific interest.

organisms that may invade the body of man or animal to produce disease, so while we use the term bacterial warfare we do not limit this paper to a consideration of bacterial diseases. We will also consider the filterable viruses, Protozoa and other pathogenic forms, as well as their toxic products.

With the powers of the world in session at Geneva discussing the future of warfare, and with some of the great nations of the world recommending the complete abolition of chemical warfare, it may appear strange to have one consider biologic warfare. I believe all will agree that while it is a mistake to live in the past it is equally undesirable to ignore the lessons of the past in prognosticating regarding the future. It is therefore well, before we consider the possible use of biologics in warfare, to discuss briefly the question, Will the nations of the world abandon the use of chemicals as an instrument of warfare?

Every advance in thought or design meets reaction and antagonism from the minds of the previous generation. It does not take some radical departure from the accepted views of the day such as marked the revolutionary concept of Copernicus or Darwin to start all "as is" conservatives on a tirade of opposition with the usual tenor of their remarks: "It is against the law of nature," "It is against religion," "It conflicts with all known law," "Even if true, it does not fit into the existing order of things." A man of middle age to-day may remember the old mossback who refused to ride on the train of the nineteenth century. In fact the train and street car had not completely overcome all the pooh-poohs of the backward ignoramus until they were involved in a fight for their very existence with a newer means of transportation—the motor. The motor vehicle had just had time to have a proper road net constructed when this engine, becoming "air-minded," needs no roads. Have they been generally accepted? Certainly; however, remarks such as, "If God wished man to fly he would have given him wings," were made in the pulpits of this country during the present century.

It takes more than the harpings of the minds of yesterday to scotch the wheels of progress. It may startle many to talk of world progress in connection with implements of warfare. However, it is not believed that any fair-minded individual can deny the place in world advancement that is due to the spirit of conquest. The peaceful shepherd, content to watch his flocks, has added little to the world's knowledge. The trader and warrior have discovered and spread knowledge. Trader and warrior are almost inseparably associated throughout history, and slowly as they may have progressed, they usually lead the thought of the day. The spirit of adventure and discovery has always marched with the warrior. The discoveries of the warrior are not limited to implements of war; however, these are the factors we wish to consider. In this field again we meet the same antagonism at every advance that the fighting man has made an antagonism that has affected all minds of the "as is" type, including conservative and reactionary individuals. Every advance, every discovery of a new weapon by the fighting man, has had to overcome two groups of opponents: (1) The fixed and established military group that is always sure the new weapon "won't work," "Is not as good as older weapons," "Not practical," etc. (2) The pacifist group—the shepherd group that considers each new weapon more terrible than the former and cries out against it.

Primitive man in his combats certainly had no weapons. Are there any to-day that believe that this early creature did not fight over "food and females"? It may be added that all combat ultimately resolves itself in the final analysis to a

strife for one of these basic biologic requirements—nourishment or sex. Fighting over gods was a later development; and these fights over gods were over a personal god, a god of the land or tribe, a god to favor their own special country, a benevolent god who would make their country a more bountiful place to live.

In the early combats man could only bite and claw and choke an adversary. This was the day of brute strength. Cleverness had relatively little value. The first man to use a weapon was the man with the best mind of his day. The first weapon used must have been very simple and elementary. Possibly a hard object held in the hand with which he brained his opponent. This weapon possibly did not create much comment. This was not an age of comment; however, the descendants of the type that could not learn to use this weapon are not numerous. Has this weapon been abandoned? Certainly not; it is an excellent weapon, and no good weapon has ever been discarded. Its use to-day is very limited because of discovery of other weapons of greater range and effectiveness.

Development of weapons has always been for the purpose of using intelligence to overcome mere physical force. The factor of range, killing an opponent before he can close with you, is a most important factor when the man of intelligence must meet superior physical force or number. Probably the first weapon to provide range was a club, possibly a sharp stick, the forerunner of the iron-tipped spear. The club may have had a stone head attached. These weapons not only advanced the clever man over the mere strong man; they aided man in his fight with the man-eating animals of the time. However, if we can make deductions from the early cave records of men of this period, advance was slow because the intelligence was of such low order that they were slow to understand and accept these new weapons. The race improved because the thinker, the successful warrior lived and won the females and left descendants; the slow and reactionary type did not live to reproduce. With every advance in weapons man is giving evidence of a desire to overcome brute strength by means of a weapon with range and effectiveness.

We can picture the introduction of the early propelled instruments, such as the arrow, causing a storm of opposition. Some youngster designed some form of propelling instrument for a sharp stick and possibly suffered the jeers of the snaggled tooth elders as he shot the sticks into inanimate targets, and only received the reward of complete recognition when he shot a sharp stick through the belly of an old pack leader to take over a band of cowed females. The progeny of this genius were of a higher order of mentality and possibly soon learned the value of organization, with the result that a tribe of arrow users developed. This seemed like the final advance, and who can doubt their ability to inflict their will on the men of the time?

The fact that the conquered men, possibly of superior physical development, considered the weapon a cruel and brutal implement that God had not endowed man with did not cause it to fall into disuse. The only thing that caused this weapon to fall into disuse and finally be practically abandoned was the development of such protection as caused the implement to cease to be effective or because other instruments were designed of greater range and effectiveness. These factors are the only things that have ever caused a weapon used successfully to be abandoned.

The outcry against the use of chemicals seems to people of this day to be quite a serious factor, and some wonder if their use will be curtailed by this influence. The following factors should

be considered before we make a decision: (a) No effective weapon once introduced has ever been abandoned until it was displaced by a more effective weapon or protection developed that rendered the instrument useless. (b) The hue and cry that attended the introduction of chemicals is not unusual on the introduction of a new weapon. The early use of gunpowder produced a reaction in every respect similar to the cry of the present-day pacifist against gas. Will the use of chemicals in warfare be abandoned? Probably not. Will the use of chemicals be curtailed? Certainly; just as certain as the race progresses, just as certain as new and more effective weapons are designed—not before this advance is made.

Will the next advance in warfare see the use of biologics? Will the next agent used be the living organisms, bacterial warfare, the scourge of armies from the most ancient times—the communicable diseases? The question of biologic warfare will be considered in more detail because here again we run into the most elaborate and fanciful statements.

A review of military history will reveal the great influence that disease has played in past wars. Results have been decisively influenced in many campaigns by epidemics of communicable disease. In some campaigns they have caused such tremendous losses and such great numbers of non-effectives that the combat has reached a stalemate. However, in certain instances, for unknown reasons, there has been a great difference in the degree to which combatants have reacted to the epidemic conditions. In a few cases we are able to understand why the communicable diseases appeared to have greater invasive power toward one of the armies; in other instances we do not understand clearly why there was a difference in the degree of involvement of the forces.

Volumes have been written on the epidemic diseases that have attacked the military forces. We will not attempt to review this extensive literature, but the doctor, especially the epidemiologist, knows that the student of history who reads only of tactics and strategy, the victories and defeats of a campaign, without familiarity with the medical history of the war, is likely to give some commander credit for success or failure that all too often has been caused by some epidemic of communicable disease. This is not meant to depreciate military success, for the great general is often a great sanitarian, and even Alexander may owe a part of his success to his doctor, philosopher, teacher—Aristotle's advice to "boil his water and bury his dung."

We must remember that we can march through the pages of military history all the way to the twentieth century before we come to a campaign where the missiles of the enemy produce more casualties than epidemic disease. In most of the ancient campaigns of any duration some one of the great military plagues did more to decimate the military forces than all the man-made munitions. I say one advisedly, although often many infections raged and famine and scurvy accompanied the communicable diseases.

What was the nature of these ancient pests? Were they diseases of that age now no longer known? No, the military pests that existed then are still with us. The Big Six of all time (war times) are: (1) The enteric fevers, typhoid and the paratyphoids; (2) the dysenteries; (3) cholera; (4) typhus; (5) the plague, bubonic plague, the Black Death; (6) smallpox.

Do not consider for a moment that the above diseases had any monopoly on the right to destroy armies. It is probable that at times influenza and the epidemic pneumonias took such heavy toll that but little fuel was left to be consumed by the Big Six. Again, under conditions where malaria is endemic, this disease is second to none in the production of non-

effectives in military ranks. In fact measles and epidemic meningitis may well be added to the list of military scourges.

This paper is not for the purpose of considering the epidemic conditions of the armies of the past, but it is realized that many individuals will naturally consider that if these infectious agents were able to produce such frightful outbreaks of disease by the simple process of chance infection under natural conditions, then in the hands of man, as a military weapon, they may well prove even more destructive. They may fail to consider the fact that the same measures that are now so efficacious against the chance infections occurring in nature may prove of equal value in combating the same agency of destruction when used by man.

We have presented biologic warfare in all its horrors; now let us analyze the problem in detail. What agents can be used to produce death and disease? How can these agents be introduced into the bodies of the enemy? We will discuss these questions in the order stated. The biologic agents available for warfare are: (1) The communicable diseases; (2) other infective processes (such as wound infections); (3) toxic products of bacteria.

The communicable diseases are well known. They are the so-called transmissible diseases that produce epidemics. They are caused by a living contagion and are spread from man to man or animal to man by various channels of transmission.. All the Big Six and the other diseases mentioned above belong to this group.

The second group, the other infective processes that are available, include such infective materials as the agents that infect wounds; gas gangrene, tetanus, anthrax and other wound contaminations that are infectious but not communicable.

The last group of dangerous agents are the toxic products of bacterial growth. We will mention but a single terror-inspiring example—botulinus toxin. A portion of this toxin almost inconceivably small when introduced into the body by any channel is lethal. We will give details later.

No one will question the effectiveness of all of these agents in producing casualties when introduced into the bodies of unprotected and non-immunized individuals. The important question then is how? How are these agents to be introduced into the bodies of the enemy to produce casualties?

Any consideration of the deliberate use of pathogenic organisms as a means of warfare will have to consider the question of how to produce a destructive epidemic in the forces of an opponent and at the same time protect one's own forces from invasion by the virulent organisms in question. Certainly at the present time we know of no disease-producing microorganisms that will respect uniform or insignia, and the use of bacteria in warfare for the destruction of opposing forces will have to be predicated upon the successful prior immunization or the complete isolation of the forces employing the disease-producing organisms through some system of quarantine.

Any intelligent discussion of bacterial warfare must certainly give detailed consideration to the question of how the living contagion is to be introduced into the individuals that are to be infected. We can well begin this investigation by a study of the channels of infection. The communicable diseases may be classified on the basis of their "routes of transmission." By this is meant the path that the living contagion follows when it leaves the body of the sick man or animal, or in some cases the carrier, to enter the body of the susceptible host to produce disease. On this basis we

may classify the communicable diseases into intestinal diseases, respiratory diseases, direct contact diseases, and insect-transmitted diseases.

The intestinal diseases are produced when some small portion, usually a microscopic portion, of the material from the intestinal canal of the sick man with its living microorganism, is introduced into the alimentary canal of the susceptible individual. Typhoid, cholera, and dysentery are well-known examples of this type of disease.

The respiratory diseases, sometimes known as "sputa borne" or even "air borne" diseases, are the communicable diseases spread by the transmission of living microorganisms from the respiratory tract of the sick to the respiratory tract of the invaded. This group of diseases is of tremendous importance and embraces such conditions as the common cold, influenza, pneumonia, diphtheria, epidemic meningitis, smallpox, and possibly of special importance for war purposes, the pneumonic form of bubonic plague.

The group of diseases that we refer to as "insect-transmitted" are those where the invasion of the new host is effected by the bites of insects which have previously fed on an individual—man or animal—infected with the disease in question. A period of incubation on the part of the insect between feedings on sick and feedings on individuals to be infected is necessary in certain instances; with other diseases such interval is not required. Examples of insect-transmitted diseases that require an interval for the development of the contagion within the body of the insect after feeding on the infected individual are malaria and yellow fever, both transmitted by mosquitoes. Bubonic plague, a disease of rats that is transmitted to man by the bite of the rat flea, does not require an incubationary period for the rat flea to develop infectiveness.

The venereal diseases are direct contact diseases. They are of profound military importance and have proved decisive factors in certain past wars, notably influencing the European campaigns of the fifteenth and sixteenth centuries. The deliberate use, however, of this means of injury is fraught with difficulties when we plan a method of securing personnel to effect the necessary exposure. The soldier's danger from the venereal diseases will not come from the open, avowed wartime enemy who loves him least, but from the money-loving or uniform-worshipping ladies who profess to love him most. Therefore, while these diseases may at times exceed all other causes of military non-effectiveness, we can dismiss them without further discussion while we are considering bacterial warfare.

It follows, then, that the communicable diseases that constitute an epidemic or pandemic threat to the military forces are the intestinal, respiratory, and insect-transmitted diseases.

The Intestinal Diseases

Mankind is all too familiar with the terrible epidemics of typhoid, cholera, dysentery and the diarrheal conditions that have destroyed military forces in the past. However, it is highly questionable if this group of diseases will ever in the future cause any such terrible catastrophes, for the reason that the epidemiology of these infections is so thoroughly understood that modern sanitary methods and immunization processes have rendered comparatively innocuous these hazards of earlier armies.

The deliberate use in warfare of these agents, however, we shall consider. While occasional small outbreaks of these diseases may be due to food infections, real epidemics of this group of diseases are traceable only to infected water and milk supplies, or to such a complete sanitary breakdown that general fecal contamina-

tion of food supplies occurs. The possibility of contaminating a milk supply presents practically insurmountable difficulties, although it is theoretically possible that spies might use such a means to discommode and harass civil populations. Of course, it has no practical application to the military forces themselves.

Contamination of water supplies of civilian communities by means of infection of large reservoirs and storage basins where the water is held awaiting consumption, is a possibility. Contamination, to be effective, would have to be subsequent to treatment by the modern water purification plant consisting of filtration and chlorination, or of course it would be valueless; but this is within the range of possibilities, and it is possible that future wars will reveal that spies will make an effort to contaminate municipal water supplies.

The use of the intestinal group of diseases against forces in the field would probably prove entirely ineffective because modern water purification methods and the close supervision of the water supply that is accepted as a necessary incident of military service will absolutely preclude the successful employment of this means of combat.

In considering the intestinal group it may be well to stress the fact that the reason modern armies, and for that matter all civilized communities, do not have serious epidemics of these diseases is not because the infective agents that cause these diseases are not present or available, but because modern sanitation protects the personnel.

Let us take a typical example, typhoid fever. The incidence of typhoid in our civil population has been greatly reduced during the present century. Let no one think, however, that this is due to any scarcity of the typhoid bacillus, and it must also be remembered that the civil population has not had any general immunization such as helps to protect the Army. Typhoid has not retreated to the outskirts of civilization; it is all about us. Every state, yes, every county in the Union, is infected. Typhoid carriers in the United States possibly number 100,000 and are generally without supervision. The reason we have only about 5,000 deaths from typhoid fever per year in the United States of America instead of about 100,000 deaths is because the great mass of our people now use water that has been rendered safe by filtration and chlorination. They consume milk that has been pasteurized and other foods that have been protected.

The same statement may be made concerning the low incidence of the dysenteries in our country. The infection is present, but epidemics do not occur because our sanitary measures are effective. We need not fear infection from without with this group of diseases; we are already grossly contaminated.

The die-hards will say that cholera is not so easily handled and is not at present a problem in America. Granted. We do not have cholera in the States; but our Army and our people do live in the presence of cholera without having epidemics of the disease. The Philippine Islands, where our Army maintains an effective fighting force entirely free from this terrible scourge, has a carrier incidence of the vibrio that causes cholera that is always high. The intestinal group of diseases will certainly not prove destructive against any civilized nation that cares to pay the price of the protection that modern sanitary methods provide.

The Respiratory Diseases

In leaving the intestinal group of diseases we proceed from the problem that represents the greatest triumph in preventive medicine to the group of diseases that baffles the best efforts of all health workers. In the control of the intestinal diseases we have so much to be proud of.

In preventing the respiratory diseases we have accomplished so little. This is stated with a full knowledge of the wonderful results that have been obtained with smallpox vaccination, and the immunization to diphtheria by the use of toxin products, as well as with a full realization of the fact that we are on the threshold of equally great accomplishments in controlling scarlet fever.

It should be noted that these great accomplishments are not sanitary triumphs such as glorify our work with the intestinal group of diseases, but immunization processes. Not being able to prevent the infection reaching mankind, we take advantage of the fact that familiarity with the organism, while not breeding contempt, does produce immunity. Therefore we use the only method that appears to offer any great protection against the respiratory diseases in nature, namely, immunization. It must be admitted that health workers can accomplish practically nothing in the way of protecting peoples from infection with the great host of respiratory invaders, and such protection as we have is due to either the natural or artificial exposure to these organisms.

In this group of diseases we find a number of maladies that are serious enough to be effective war weapons if ways of using them can be devised. However, before proceeding we should call attention to the fact that in this group are also a large number of diseases that are not suited for military purposes. For instance, smallpox, while a very serious epidemic disease, must be dismissed immediately. All military forces are immunized to this dreadful scourge, and we can therefore dismiss it from further consideration.

Many of the diseases of childhood, while constituting a military problem at time of mobilizing rural recruits, are not suitable for military purposes for the reason that the factor of age susceptibility plays so much importance when we consider the entire group that comprises our population. As an example we may mention diphtheria. While in childhood a very high percentage of the population is susceptible to this disease, the great majority of these same individuals develop considerable natural immunity to the organism that causes diphtheria without further interference than the normal aging. Therefore, while we see epidemics of diphtheria in schools and orphanages, we do not encounter serious outbreaks involving large numbers of any adult population. This disease is cited only as an example wherein the factor of age susceptibility is important; there are a number of diseases that show this phenomenon and would therefore be unsuited as offensive military weapons.

Certain diseases, such as influenza, pneumonia and the common cold, do not show a marked tendency to limit their injury to any one age group and would be efficacious if they could be used against military personnel. Mankind is as helpless to-day as at any period in history in the control of these diseases; also they are very serious conditions that produce great numbers of non-effectives, and in the instance of the epidemic pneumonia they result in a tremendous mortality.

Before we surrender to the individuals who threaten such frightful havoc with this group, we may well ask how they are going to start an epidemic of influenza, pneumonia or the common cold. If they answer that they will introduce the germs that cause these diseases we can well laugh at them. The process is not so simple. The factors that make respiratory epidemics are not so elementary. They include not only the infection of the individual, but the question of the resistance of the infected animal. The organisms that cause these diseases are all about us. They are always with us. Epidemics mean more than simply infec-

tion; they mean the rapid transfer from individual to individual of these infective agents. They mean a lapse in the immunity of the invaded, and possibly something else.

I do not know of a bacteriologist or an epidemiologist who can tell you how to start a respiratory epidemic unless the stage is especially set. I know many who are certain that whenever you place a large group of individuals, man or beast, under poor hygienic conditions, with overcrowding, poor ventilation, and exposure to unfavorable climatic conditions, or other factors that decrease resistance, respiratory outbreaks will occur in spite of any precautions that can be taken, and that if large numbers of highly susceptible individuals (rural populations) are present the outbreak can be expected to assume epidemic proportions.

It is also worthy of note that when epidemic conditions prevail certain organisms may possibly have greater invasive power, for then apparently populations that were not so susceptible or readily invaded may be attacked when they previously escaped injury. It will be noted that as in the case of the intestinal diseases, so with the respiratory diseases it is not a simple case of introducing infection that constitutes a menace. The organisms that produce most of these diseases are always with us, and epidemics mean more than infection. While we can not understand exactly how epidemics start, and we question the ability of a military agency deliberately to produce an epidemic of one of these diseases, we feel certain that if bacterial warfare is ever contemplated they will not think of using the respiratory group of invaders for the reason that quarantine, isolation, and all other methods to control diseases such as influenza, are practically valueless. The torch once set off might destroy friend and foe alike, and would therefore prove of no value as a military weapon.

The two diseases in this group that are most frequently mentioned are influenza and epidemic meningitis (cerebrospinal fever), possibly because of their importance during World War I. All that has been stated above applies with especial force to influenza, where in addition to the fact that no one knows how to control this disease, we must add that we are not even positive about the actual organism that causes the condition. Epidemic meningitis, on the other hand, is a very definite, specific disease due to a very well-known organism. We must admit at the outset that this is a very serious disease, and that it often assumes epidemic proportions in military organizations. However, if we stop to consider the nature of the organism and the epidemiology we see how entirely unsuited epidemic meningitis is for use as a military weapon. The organism, the micrococcus of Weichselbaum, is so delicate that even on the most favorable culture media it rapidly dies when exposed for even a few hours to temperatures much below that of blood heat. This disease is spread by carriers, and the organism must be introduced almost directly from the nasal pharynx of the carrier to the respiratory mucous membrane of the individual invaded or it will be destroyed by the unfavorable temperature conditions while en route.

Those individuals who think this disease may be used for military purposes will answer that carriers in the forms of prisoners, etc., would be introduced into the opposing forces. To those who know anything about epidemic meningitis this suggestion is ridiculous. Any military aggregation of any great size already has so many carriers present (anywhere from 2 to 30 per cent.) that the introduction of a few more or less is of no moment. Epidemics of meningitis occur only when *overcrowding* is associated with conditions that lower the general resistance, as exposure, unfavorable climatic conditions, and fatigue. Meningitis is, and

probably always will be, a military problem; but the individual's friends and associates, not the enemy, are the great problem with this disease.

We will not take up in detail all the various respiratory diseases. The tabulation would prove tiresome, for the story would always be not so much a question of the great danger of the introduction of the infective agent, but the creation of epidemic conditions, a soil in which the organism could produce an epidemic, overcrowding, and lessened resistance.

The Insect-transmitted Diseases

These diseases will probably most certainly influence wars of the future as they have in the past. An invasion of such a country as Mexico, at the present time, could constitute more of a sanitary than a military problem. With malaria, dengue, and possibly even yellow fever along the seaboards, and typhus endemic in the plateau district, our main problems would be sanitary. Bubonic plague might also be encountered here as well as in any other place. This disease, bubonic plague, is the disease entity that many consider best suited for military purposes. To begin with, it is a frightfully serious malady, a decimating disease that has most profoundly influenced warfare in the past. It is possible that the rise of the Mohammedan world was due to a great extent to the fact that Europe was in the throes of the greatest scourge mankind has known, the plague, at the time that Mohammed's followers were ready to organize and extend the influence of the crescent until the horns were about to encircle the Mediterranean. Certainly these Arabian tribesmen had never shown any signs of military greatness or valor prior to this period, and it is probable that their religious ardor would have met with small success against the well-organized nations of the time if these nations had not been practically exsanguinated by the "Black Death."

The use of bubonic plague to-day against a field force, when the forces are actually in contact, is unthinkable for the simple reason that the epidemic could not be controlled. Infected personnel captured would provide the spark to set off possible outbreaks of pneumonic plague in the ranks of the captors. Infected rats would also visit and spread the condition. An advance over terrain infected with plague-bearing rats would be dangerous. Therefore, except as a last desperate, despairing hope of a rapidly retreating army, the use of plague by forces in the field is not to be considered.

The use of plague to harass civil populations presents less difficulty than the use of the organisms against a field force. Those who think that plague will be used as an offensive weapon consider that civil communities may be infected by introducing plague-infected rats. Of course this is easier to state than to accomplish, but it may be possible for airplanes flying low to drop recently infected rats. At least this is the statement that the individuals make who consider the use of this weapon feasible. Even with so terrible a pandemic disease as plague, however, there is a great deal more to the question of epidemics than mere infection. For instance, to cite an example, one that Gill so forcibly states, "Not half a dozen cases of plague occurred amongst Europeans (including British troops) stationed in the Punjab during the year 1924, when about 500,000, or one fortieth of the indigenous population suffered from the disease."[3] If these intelligent people were able to avoid the infection when residing in an environment that was literally infiltrated with the infection, it certainly should be possible to control bubonic plague in a population such as we have.

[3] C. A. Gill, "The Genesis of Epidemics." London: Baillière, Tindall and Cox, 1928.

For that matter, the question of plague is not a condition that takes us to the outskirts of civilization. Our own Pacific Seaboard became infected in 1900, and following the San Francisco earthquake the infection extended and is now more or less endemic as a rodent disease involving not only rats but ground squirrels. Here again it is not a question of can we control the infection; we are controlling it, and have not had an outbreak of human plague of sufficient size to designate as an epidemic.

The other insect-transmitted disease that is most frequently assigned a place of importance as an agent suited for warfare is typhus. This disease is certainly terrible enough to satisfy even those individuals who are anxious to preach the gospel of frightfulness. The military and civil populations that have been destroyed by typhus bear witness to how effective this agent of destruction can be. However, again we have a condition that is easily controlled. Complete solution of the problem of endemic typhus is not yet in print, although it is probable that the work of such men as Dyer, Maxcy and Zinsser will soon offer a complete explanation of how this scourge simmers along during the interepidemic periods. Epidemic typhus is thoroughly understood. The epidemiology is so simple that it can be embraced in the name of the transmitting insect, the body louse. The control of epidemic typhus is the simple question of the control of louse infestation. Of course quarantine will help to prevent the introduction of the infection, but quarantine is futile if the Army is allowed to become lousy. The lousy Army may become the victim of typhus, even in America, without the introduction of infection from extraneous sources. The weight of opinion in the best epidemiological minds is that, as Maxcy suggested, endemic typhus is probably carried over between epidemics in a rodent reservoir. Endemic cases occasionally occur when transmitted to man by an insect, and when the infection is passed from man to man by the body louse, with the resulting enhancement of virulence, epidemics may be expected to result.

The difficulty of starting an epidemic of malaria, yellow fever or trypanosomiasis (sleeping sickness) appears to be obvious, for no one has suggested the use of these agents. Those who understand the epidemiology of these diseases know they are not suited for war purposes even though they realize the problem they present to military forces in endemic areas.

This completes consideration of the communicable diseases. We have discussed in some detail practically all except the direct contact group. The only diseases of this group of great military importance are venereal, and we have given our reasons for dismissing this group from consideration.

The Infective Processes

Certain disease processes that affect the tissues are caused by living organisms and are therefore designated as infective, even though they are not considered communicable in the sense that they tend to be transmitted from man to man. These disease processes include such infections as tetanus, gas gangrene, anthrax and the ordinary pyogenic (pus formers) invaders. The agents that produce these infections have all been mentioned as possible war weapons, and it must be admitted that so far as the first three are concerned, with some scientific judgments on the part of their sponsors.

The agents that cause tetanus, gas gangrene and anthrax are not delicate organisms such as the relatively short-lived, easily destroyed pathogens that cause most of the communicable diseases. They are very resistant, spore-forming organisms, generally capable of a pro-

longed period of viability without loss of virulence, even when separated from the animal tissues. It is not surprising, therefore, to find one of this group (anthrax) selected as the infectious agent best suited for military purposes by a science student preparing an undergraduate thesis on "Bacteriologic Warfare."[3]

The selection of anthrax does credit to his training: in fact the entire study shows more intelligent thought than any article that has come to the attention of the writer. His description of the characteristics of the proposed bacterial invader are worth quoting:

> What shall we say are the requirements for a perfect military pathogen? It attacks preferably both man and animals. It must be quick-acting, highly virulent, and capable of causing disease in small quantities. It must be highly resistant, capable of surviving outside the body under the most adverse conditions, and even resisting partial cooking or a careless attempt at sterilization (a spore former). The causative organism should be able to force its entrance through all the avenues of infection; respiratory tract, alimentary tract, and breaks in the skin. The disease should not be too actively contagious, and it must be very well understood, for pathogens should never be used without contemplating the possibility of their getting out of control. Finally, and perhaps most importantly, it should be possible to obtain large quantities of the pathogen in virulent strain and spore form with the least possible manipulation and delay.

After this excellent description of the perfect hypothetical agent, he selects anthrax as the agent best suited to meet the requirements of a bacterial weapon. I can not agree with Pentler that "Anthrax satisfies the requirements almost perfectly"; but I believe all bacteriologists will agree that he has selected the agent that most nearly meets the requirements he has so well outlined.

These spore-forming invaders are a real problem. Tetanus and gas gangrene are pathogenic processes that have always been associated with gunshot wounds and are therefore of special interest to the military surgeon. They do not produce epidemic diseases, however, and they are not communicable. They have to have a portal of entry made for them, a wound, and while the use of these organisms to contaminate battlefields might cause an increase in the number of cases of tetanus and gas gangrene, they would not increase the number of casualties. They would only complicate the treatment of those already disabled. It might be added that we have an entirely satisfactory serologic prophylactic agent for tetanus, and that as a result of the surgical advances of the last fifty years, gas gangrene is less frequent than in the pre-bacteriologic days.

We can not dismiss anthrax so readily; however, it is worthy of note that although anthrax is almost a world-wide disease, nevertheless anthrax infection of gunshot wounds is practically unknown. If gross contamination of battlefields with the organism of anthrax is effected it is granted that cases of anthrax infection of wounds will occur, and possibly some few cases of infection in individuals who have not been wounded; but when we consider that human epidemic anthrax is unknown during the bacteriologic era, I question if we need fear greater danger from this organism than contamination of wounds.

It will be noted that up to this point we have not discussed the technical difficulties that a military force would have in contaminating a hostile force. The difficulties in the case of the communicable diseases are so obvious that they need not be mentioned. The epidemiologic factors make the communicable diseases unsuited for offensive military use. The causative organisms are all either short-lived when separated from the living tissues or else readily destroyed by ordinary routine sanitary precautions.

[3] C. F. Pentler, "Some Thoughts on Bacteriologic Warfare." Massachusetts Institute of Technology, Department of Biology and Public Health.

We can not make this statement concerning the highly resistant infections such as tetanus, gas gangrene and anthrax. These agents are admittedly the most dangerous; but it must be remembered that to be dangerous they must be alive, and that many technical difficulties present themselves when living agents are to be used that are not present when missiles and chemicals are used. Shells can be used to project missiles and chemicals on to an enemy many miles distant; but bacteria can not be used in this way. No living organism will withstand the temperature generated by an exploding artillery shell. Airplanes may contaminate terrain, but their effect would be quite local and probably less dangerous and less certain than high explosives used in the same way.

It is not maintained that bacterial contamination is impossible. A retreating enemy may hurriedly contaminate the terrain that is to be evacuated. However, it is believed that the use of living organisms in offensive warfare presents technical difficulties that are not generally considered. The contamination that spies and other individuals could effect, using the only really effective agents we have mentioned—the highly resistant, spore-forming organisms that are so dangerous to wounds—would prove too local to be of any value whatsoever.

Toxic Products

The forms of bacterial warfare include not only the possible distribution of living organisms in the force of an enemy but the possible use of toxic products derived from bacteria. Certain of our bacterial toxins are the most deadly poisons known. The toxin of the bacillus botulinus is so powerful that instances have been recorded where toxins have been produced so toxic that .005 milligram would kill a 250-gram guinea pig. This material, botulinus toxin, is poison for man. It is possibly the most toxic agent known, and will produce the lethal effect in any way that the material is introduced into the animal. If consumed with food, injected into the tissues or even dropped on the mucous membrane or conjunctiva, it is equally deadly.

This must be the material referred to when we read such dramatic statements as the following: "An airplane can carry sufficient toxins to destroy an entire city." Such statements have an element of truth in them. In fact they are conservative. An airplane could carry enough of the botulinus toxin to destroy every living man in the world *if* administration of the toxin was as simple a process as production and transportation.

There were over one hundred billion bullets manufactured during the World War enough to kill the entire world population fifty times; but a few of us are still alive. It is easy to calculate the lethal (fatal) dose of a toxic agent; but do not think it is so easy to figure on the casualty-producing power of a military weapon.

The hostile aviator will not be received with a welcome, nor can he expect to land at an air field near any large city and find the entire population lined up ready to accept the carefully measured lethal dose of botulinus toxin.

The release of tremendous quantities of botulinus toxin over a large city may produce human casualties; however, the extent of the damage might be only the wholesale destruction of rodents, sparrows and possibly numerous cats and dogs—not such a serious loss in time of war. It is difficult to evaluate properly the possible effects of the bacterial toxins. Certainly such statements as an airplane destroying an entire city with toxins is ridiculous; but they may have a value comparable to chemical agents, with this great disadvantage, however: bacterial toxins are readily destroyed by heat; therefore, like bacteria, they are unsuited for use in shells.

Animal Diseases

The use of living organisms to produce disease in live stock, such as horses and mules needed for transportation of Army equipment and supplies, has been mentioned as a possible form of bacterial warfare. It is believed that the difficulties here are quite similar to those mentioned for diseases attacking man, with this great advantage to the defense that the veterinary officer will have in controlling epidemics. The veterinary officer can destroy any animal or group that he considers a menace to the health of the animals in the Army. The medical officer can not take such steps to control epidemics that threaten human populations.

If we expand the term bacterial warfare to embrace such phases of biologic warfare as will include the agriculture pests, then an additional factor to consider is the fact that spies and possibly hostile aviators might inoculate growing crops with such pests as the boll weevil, the corn borer, the Mediterranean fruit-fly and like destructive agents. These agents in most instances, however, take so long to invade sufficient terrain to be effective in destroying crops that their value in actually overcoming the resistance of a foe is questionable. They take several years to advance over a large area, and might prove an economic problem years after the war has been completed; therefore, they violate one of the fundamental ideas in warfare, since they would interfere with the ability of the conquered nation to pay the victors for the beating they had received.

Conclusions

It is believed that it has been shown that the development of implements of warfare represents an evolution based on the gradual application of the improving mind of man. The one factor of importance in this development has been effectiveness. It has been a question of the good mind versus the strong back; of the thinker versus the lifter. It is believed that the future of warfare will be based on the same principles. It is therefore apparent that the question of whether chemical munitions will be used or not and whether bacterial warfare will be used or not will depend on their practicability rather than on the sentimental reactions of pacifists.

I consider that it is highly questionable if biologic agents are suited for warfare. Certainly at the present time practically insurmountable technical difficulties prevent the use of biologic agents as effective weapons of warfare.

AN ANTHROPOLOGIST IN MODERN RUSSIA

By Dr. A. HRDLIČKA

UNTIL APRIL, CURATOR OF PHYSICAL ANTHROPOLOGY, U. S. NATIONAL MUSEUM

THE last trip, in 1939, and a necessary "cap" to the Alaskan explorations. Must see in England and elsewhere the late discoveries of early human remains, and then the Siberian skeletal materials in the Russian museums, for comparison with those of our Alaskan explorations.

Leave New York, April 15, on the *S.S. Aquitania,* one of the largest and best of the transoceanic steamers, in seemingly full health and not even tired; and the trip is uneventful until two days before arrival when, on the top deck, due to an unexpected roll of the boat, twist body and sprain or tear something in the chest, under the lower part of the sternum, which results in more or less continued raw pain in that locality. From that time on lose appetite, can not walk as much as used to on decks, and can not sleep well. The next morning fairly easy, but aggravate condition by playing shuffleboard on a wet deck—every shove rouses more the severe pain under the sternum, until I have to give up. Reach London, nevertheless, though somewhat strenuously, and next day spend whole forenoon in slowly walking from place to place and attending to things; but in the afternoon condition aggravates, can not rest any more in any position, slight feverishness—evidently something more than ordinary, and so must get help. Walk rather painfully to the University Hospital, which I saw last night when looking over the anatomical department of the university where in a few days I was to give some lectures—

ON A SUNNY AFTERNOON ON ONE OF THE NEW STREETS OF LENINGRAD

MOST OF THE CITY IS GRADUALLY BEING REBUILT WITH SUCH STRUCTURES AS THAT ON THE LEFT.

ONE OF THE NEW RUSSIAN HIGH SCHOOLS IN LENINGRAD
THESE ARE ENTIRELY MODERN INSTITUTIONS. THE CLASSROOMS, DECORATED WITH PICTURES AND FLOWERS, PRESENT A VERY CHEERFUL ATMOSPHERE.

they hurry me to a bed, diagnose coronary thrombosis, and the next six weeks have to spend in the hospital—the first vacation of my life, under the best possible care, with more friendliness than I deserved and in conditions for which I never can be enough thankful.

But the tasks called and so, after giving in London two of the lectures, which did me good, and seeing the important Palestine remains, which furnish the "missing links" between present man and the Neanderthalers, left on June 3 on the Russian boat *Sibir*[1] for Leningrad. And from that time on was with the Russians, who almost killed me with their kindness. In Leningrad, one of the most outstanding cities of the world, could still not walk more than a few blocks at a time, and that very slowly; but as long as needed they sent every morning a car for me, and took me home again at night, facilitated my work in every way, and provided care by their foremost specialist in heart troubles. And I kept on very slowly but steadily getting stronger, until it was possible to undertake the trip to Siberia, and there even to make three little field expeditions.

A more formal brief report on the trip to the Soviet Union was published in the "Exploration Volume" of the Smithsonian for that year and need not be repeated; but much could be said of a more general nature. I have this time, however, not kept a journal, due partly to still weakened condition and partly to the overwhelming amount of what I saw and heard. Having been in the country twice before, in 1909 and in 1912, I was able to note to some extent what happened to it and what was now going on, and will put down a few of the outstanding impressions. These are not colored with any "ideology," for I am an inborn democratic individual.

[1] Since then turned into a hospital ship, and as such sunk on August 19, 1941, by German bombers, with the loss of 400 wounded, women and children.

In 1912, shortly before the World War, Russia was a typically bureaucratic, military and antiquated-church country, with some admirable museums and institutions, but in general subdeveloped industrially, with much poverty and with a mass of good but retarded population. A very large majority of the people lived in drab villages, were over 70 per cent. illiterate and in the vast country worked, as well as lived, in a more or less primitive fashion. The war of 1914–17, the revolution in 1917 and the civil war of 1918–23, blighted and damaged most of the cities, and largely destroyed the railroads and other utilities. The scars of all that were still visible now, in 1939, but vast changes have taken place since 1923 in many things. Leningrad and Moscow have more than doubled in population and have widely extended territorially. Leningrad towards the southeast, especially, is becoming a great Russian-type metropolis; while Moscow is being largely rebuilt according to plans that appear almost fantastic, and is already in every way one of the greatest of modern cities. There is a steady destruction of the ugly or what is in the way, and restoration of the worthwhile, with much solid and characteristic new construction. Cities all over, in fact, have become largely industrialized; the drab old villages are being changed into attractive small towns. Everywhere one sees the building of new schools, clubs, theaters, movies, hospitals. The old hospitals, still numerous, are not all that could be desired, but are generally well furnished and their defects are being corrected; the new ones are all that medicine could wish for. There are numerous large and smaller new hotels, well built and furnished, even though the plumbing and sewage in some of them in the provincial towns are not yet perfect. Life everywhere is humming, the people are in a mental ferment, illiteracy is largely gone, there is a striving in all directions, and a gen-

CHARACTERISTIC DAILY SCENE IN ANY OF THE MANY RUSSIAN MUSEUMS
IN ALL THE MUSEUMS THERE ARE DEMONSTRATORS, MOSTLY WOMEN, WHO TAKE GROUP UPON GROUP OF VISITORS THROUGH THE COLLECTIONS, EXPLAINING EVERYTHING OF NOTE.

IN THE "PALACE OF THE PIONEERS"
THE "PIONEERS" ARE SIMILAR TO BOY AND GIRL SCOUTS IN THIS COUNTRY AND IN ENGLAND.

IN A "REST HOME" FOR SCIENTISTS
RUSSIA IS AHEAD OF US IN THIS RESPECT.

eral hunger for knowledge. Every one appears to be working, reading, meeting, discussing. Radio is everywhere, even on the top of corner houses in the large cities, in the cars on first-class trains and in the villages. Deep under Moscow is the finest subway in existence, with stations that are truly like underground palaces. There are modern street cars, buses, electricity not only in the cities but also already in many of the villages. And there is no end of other matters of interest to a visitor.

For the anthropologist, however, the subject of main concern are the humans, and here, too, there was witnessed a great deal. Saw, even in faraway Siberian villages, clean cheerful nurseries and kindergartens; groups upon groups of sunburnt tots with their woman guardians roaming like so many near-naked sprites through woods and along banks of streams or pools. Older children, fittingly dressed, with red ties, are the boy and girl scouts; and of the still older ones and young adults, the "phys-culture" youth, one sees whole large columns of them, marching, exercising, singing, on squares and broad streets, after work hours, to music furnished without pay by bands of workers. The whole population seems to have been rejuvenated, old people to have largely vanished. To see a bewhiskered man in the cities, and even in much of the country, was not far from as much of a rarity as to see a horse in our capital. Even the drinking habits have changed, the old vodka being largely replaced by soda waters and beer. And there is any amount of ice cream being sold on the streets of the cities. The military are everywhere, but they are unobtrusive, just strolling about, visiting museums, galleries, theaters, without weapons. As to policemen, in my three weeks in Moscow, not counting the one guard before every legation, in all my roamings I saw but two. Though I went wherever I wanted, never once had I been stopped,

THE CHILDREN OF RUSSIA IN THE COUNTRY AND CITY

Top left: CHILDREN IN A GARDEN. AS THE PEOPLE HAVE BEEN ESSENTIALLY AGRICULTURAL FROM TIME IMMEMORIAL, THE CHILDREN ARE NEVER HAPPIER THAN WHEN IN THE FIELDS OR GARDEN. *Top center:* ONE MEETS MANY SUCH GROUPS OF TOTS IN THE FIELDS AND WOODS EVERYWHERE ON A NICE SUMMER DAY. *Top right:* A CLASS IN EMBROIDERY. THERE IS MUCH FOLK ART IN ALL PARTS OF RUSSIA. *Bottom:* THE DIRECTOR OF THE FIRST TRADE SCHOOL AT A PLANT IN MOSCOW SHOWING STUDENTS THE TURNING LATHE SHOP WHERE THEY ARE TO WORK.

or followed, or even ogled, though my clothes must have shown that I was a foreigner. There were formalities to attend to with the passport, but no others. I saw many poorly furnished stores, still many old and gloomy yard houses, and only simply clad people; but little or no dirt, no disorder, no idlers on street corners, and but very few and that secretive beggars. The service in some of the hotels was slow and not very apt, but the food was plentiful, though at first when

I came there was a shortage of vegetables.

The museums, libraries, the many theaters, and the numerous movie houses, were invariably full to capacity. The thirst for reading was such that the newspapers and printers of popular books could not catch up with the demand. They publish both journals and books in vast editions, yet even these were seldom sufficient. One morning I wanted to get a newspaper. On the other

A FINE RUSSIAN TYPE
THE PEOPLE ARE GREAT LOVERS OF FLOWERS; THE WRITER, SOMEWHAT TO HIS EMBARRASSMENT, RECEIVED AN ARMFUL WHEN HE WAS LEAVING MOSCOW AND AGAIN WHEN LEAVING RUSSIA.

side of the square facing the Metropole Hotel where I stayed was a kiosk where the paper could be bought. To these kiosks a car would bring so many copies every few hours, and there was always a long line of people waiting for the delivery. When I came over that morning I counted 132 in front of me, and before I could get near the stand the papers were all gone. There are no yellow papers, nor yellow, lurid or loose literature.

Many of the people one met in the large cities reminded one of a sound country girl who suddenly was transplanted to city conditions and did not quite know as yet how to walk in them—but was fast learning. And, though there was no display anywhere of riches, I saw no slums comparable to those in other countries.

The museums I found, for the most part, in excellent condition, and the others being restored. One does not readily take to the numerous white-on-red slogans in the museums, nor the slow old service in some of them, or the tea-habits during office hours; but could not help but admire much that had already been accomplished by the young staffs and their eager interest in their work.

In general, I saw a new human world in the current of its formation, with remnants of the past still hanging to it like the pieces of last year's bark on a fruit tree, but with the renewed tree already bursting into flower and promising a great harvest. And while I did not understand some of the propaganda, I saw much wisdom in many things and an accelerating crystallization of a new existence, virile, generous, successful, and of a highly promising ultimate service to humankind in general.

Let us leave Russia to its own evolution. This is not and can not be our, American, evolution, for our past as well as present, our conditions and the nature of our people are different. We too can evolve, and are evolving; but as they learn our best from us, may we also tolerantly and in a friendly way observe and perhaps learn from here and there what is done and reached by them, as well as by other striving human groups in other parts of the world.

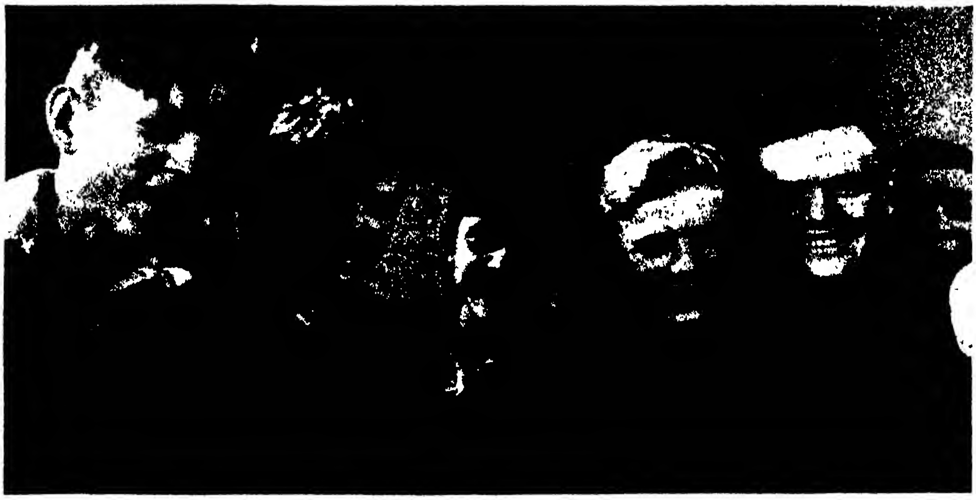
The trip to and through parts of Siberia was a revelation. Since 1912 everything has changed so that I could recognize but little more than the forests.

A YOUNG WOMAN WHO HAS LEARNED TO OPERATE A FIELD TRACTOR

THERE ARE MANY THOUSANDS OF SUCH WOMEN IN RUSSIA WHO LIBERATED THE MEN FOR WAR; ACCORDING TO SOME TESTIMONY, THEY ARE PROVING VERY EFFICIENT. WOMEN TAKE PART IN INDUSTRIES OF ALL SORTS, MUCH MORE SO THAN IN OTHER COUNTRIES.

RUSSIAN TYPES OF THE PRESENT DAY

AN OFFICER WHO PARTICIPATED IN THE FIGHTING WITH THE JAPANESE AT LAKE KHASAN IS TELLING OF HIS EXPERIENCES TO THE MEN AND WOMEN OF A LENINGRAD INDUSTRIAL ESTABLISHMENT.



A GROUP OF YOUNGSTERS FROM A MOSCOW TRADE SCHOOL
THESE BOYS HAVE CHARACTERISTIC YOUNG RUSSIAN FACES. NOTE THE FINE DENTURES.

The cities have grown greatly and become industrialized, while the country—vast parts of it—is turning agricultural, a repetititon of the story of our West since the nineties of the last century—a new world in the midst of its formation.

And an endless procession of trains with soldiers, cannon, ammunition, even some whole steel river boats, with now and then a crowded train of immigrants, all proceeding eastward. It was the time of the little war with Japan, and Siberia was pouring its armed forces towards the Pacific. In Irkutsk, my stopping place, and especially in its environments, there were many soldiers, though there was no excitement and everything went on normally. The city had suffered much during the late wars. Its fine former museum and library were gone, but the contents, I found later, or at least much of them, lie preserved in the vaults beneath an old church and will see daylight again when there is a new museum, which is in contemplation. Some day, and that not far off, when the mighty swift Angara that surrounds the larger portion of the city, is harnessed and gives its tremendous power, Irkutsk will become one of the most important Siberian centers.

Irkutsk, moreover, lies in a region which is one of the richest for human prehistory. Along the rivers of this beautiful region men lived from the upper paleolithic time and especially during the neolithic period, leaving behind many of their cultural remains, and also their skeletons. And the neolithic skulls and skeletons, of which already a large series has been recovered and are preserved in the present pro-museum, have shown themselves to be of exceeding importance for the study of Asiatic-American ancient connections: they are very close to those of certain types of the American Indian.

Due to the kindness of the head of the local university, the head of the temporary museum and the local scientists, I was not only able to see and utilize all the locally preserved collections, including those in the vaults, but I was able to make three trips along the Angara River and participate in some remarkably careful excavations carried on in the old sites along the river by Professor Okladnikov and his wife, who were from Leningrad. My everlasting gratefulness to all these friendly people.

During my observations over the

Soviet Union, I became deeply impressed with its anthropological opportunities. It would be of the utmost value to the science of man if it would follow and bring to light the physical as well as other changes which under the new form of life, with its culture, sanitation, better nourishment, care of the child and universal physical exercise of the youth, must be taking place. And it would further be most desirable to study the results of the intermarriages which are taking place on a great scale between the many nationalities composing the population.

On return to Moscow, much strengthened, gave two conferences at the Museum --one, for a wonder, in Russian. It must have been a mighty lame Russian; but they claimed they understood. This lecture was on "The Future Museum of Man" in Moscow. Also gave a demonstration of our cast making.

And then, with regret, had to leave, for the skies over Europe were heavily clouding. . . .

A strange thing. Before I came I had a notion that I would find everything different in social conditions—and I did not— not in the human essentials. What differs more or less are the views on matters, and the ways of doings; and even these are still largely in the process of crystallization. I wanted foremost of all to learn what really is, in Russia, a "communist"—searched for a definition or at least a brief description, and failed to get it. What I heard and saw was hard to believe, and I hardly dare to say it lest I might appear biased or deluded.

SEVERAL ASPECTS OF THE LIFE OF CHILDREN IN RUSSIA

Top left: PHYSICAL CULTURE GROUPS. *Top right:* A LITTLE BAND OF SMALL CHILDREN, TANNED AND HEALTHY FROM MUCH OUTDOOR LIFE. NO COUNTRY TAKES GREATER CARE OF ITS YOUNG PROGENY THAN DOES THE SOVIET UNION OF THE PRESENT DAY. *Bottom left:* THESE COUNTRY BOYS LIKE FISHING AS DO BOYS EVERYWHERE—AND THEY CATCH ABOUT EQUALLY AS "BIG ONES"! *Bottom right:* YOUNGSTERS BRINGING BIRD HOUSES INTO THE WOODS.

A CLASS IN BOTANY AT A RUSSIAN AGRICULTURAL INSTITUTE
THE DEMONSTRATION EQUIPMENT OF PLASTIC MODELS AND FRAMED PRESSED SPECIMENS OF PLANTS ARE MUCH LIKE THOSE USED IN AMERICAN SCHOOLS TO-DAY.

It seems that by far not everybody is or ever can become "one of the Party"; that the requirements are outstanding character and achievements; and that his or her main duty is to use and further develop these qualities for the benefit of what they call their "family" and we call our country. And they are developing and using them, until in some ways they have already outstripped most other peoples. I saw the results and could not but give credit. A line of these, which I had the occasion to test personally and found most grateful, were the excellent forest-park "rest-homes" for scientists. Even we as yet have nothing of this nature.

It was all confusing; and when a co-passenger on the return trip asked me "What is a communist?" I could only answer "I do not quite know." Wonder if anybody else does, outside of Russia. Our variety, it is plain, is something quite different. . . .

A question asked by many on the way out and at my return, was "How did they treat you?" to which I could only answer that, so long as they did not know where I came from, they did not "treat me at all," I was left completely to my own ways; but that as soon as I said anywhere I was an American, they did me such favors until it shamed me. In all my travels in Russia on this as well as the former two trips, I can say with all sincerity that I have never heard a single word against America; again and again the Russians said, "We have but two enemies in the world, one in the west and one in the east." As to America, they thought we did not understand them; and they constantly gauged their industrial and other achievements with ours—with much respect for ours. . . .

NATURAL HISTORY OF TERMITES

II. THEIR SOCIAL ORGANIZATION

By Dr. VICTOR W. VON HAGEN

FELLOW OF THE ZOOLOGICAL SOCIETY OF LONDON; SANTA MONICA, CALIFORNIA

All termite colonies, without exception, begin with a pair of male and female termites who have de-alated (unwinged) themselves by snapping off their four wings at a humeral suture at the base of the wing. Emerging from the darkness of their nests, the winged termites take to the air, not to swarm as does the bee or wasp (for fecundation does not take place in the air), but more as a form of dispersal for the incipient colony. From a termite colony of, say, a hypothetical 300,000 individuals, a third of this population are the winged caste. Normally, in the dark nests, they, like the other termite castes, flee from light; but during the swarm or dispersal, they have a reversal of these instincts. Upon gaining egress to the open, an instinct is developed to move toward the light. Any one having had a residence in the tropics will remember on the nights of the first rains

THE ALATES—THE REPRODUCING FACTORS OF TERMITES

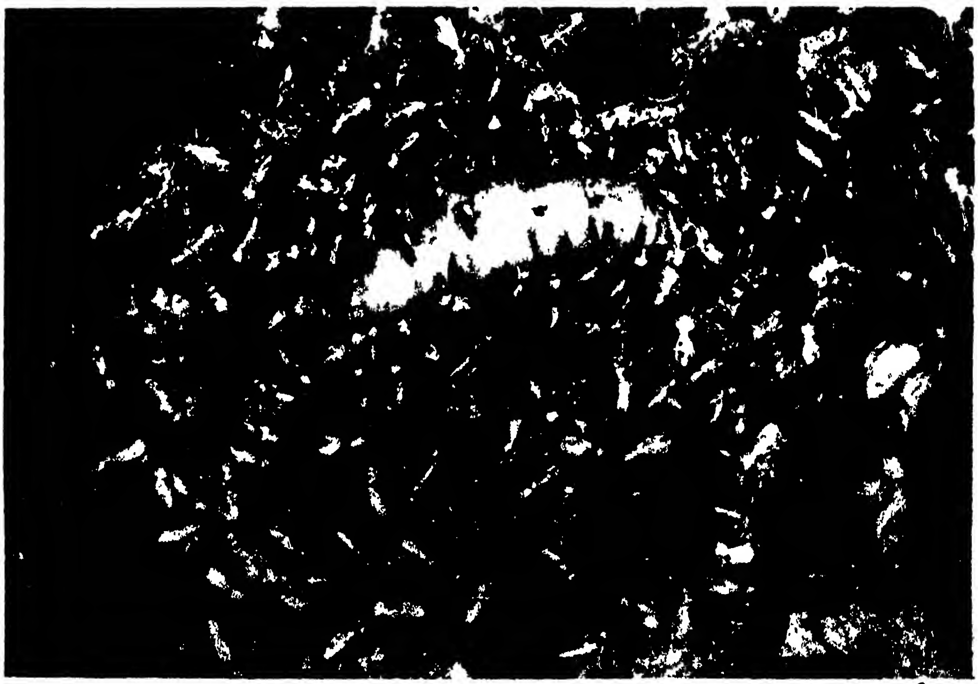
IN THE TERMITE COLONY THE WORKERS AND SOLDIERS ARE USUALLY STERILE. REPRODUCTION IS CARRIED ON BY FERTILE CASTES, BOTH MALE AND FEMALE. THOSE WITH THE WINGS HAVE SWARMED; THE SMALLER DARKER FORMS HAVE DE-ALATED THEMSELVES, LEAVING ONLY SMALL STUMPS WHERE THE WINGS WERE ATTACHED. THE WHITE FORM IN THE CENTER IS BRACHYPTEROUS. IT NEVER LEAVES THE NEST, AND THE WINGS NEVER ARE DEVELOPED. THESE FORMS BECOME SUPPLEMENTARY QUEENS, MAKING COLONY BUDDING POSSIBLE WITHOUT SWARMING.

the myriads of winged termites flying about light-bathed areas forming a vortex of gyrating insects. Of this hypothetical 100,000 of swarming termites, but a fraction live to begin a new colony; birds, frogs, lizards, snakes, ants, insectivorous mammals and even man instinctively and knowingly come to the parts where the winged termite is emerging and consume them eagerly.

As soon as they have dispersed themselves, the winged termites fall to the ground and pair off. The de-alated female termite then lifts her abdomen, emits an attractive chemical odor that attracts the male, which places its labium to the base of the abdomen of the "fairer sex," and follows after the female in an intricate and thoroughly bewildering movement, the male remaining so close to the odoriferous anal parts of the female, it seems as if they are actually attached.

After this thoroughly exhausting tandem, the two termites, male and female, set off together, enter some cranny—a part of an old log or under the bark of a tree—and there mate and begin a new colony, the impregnated female laying within a relatively short time eggs which develop into neuter workers and soldiers.

This curious phase of the termite's biology—the institution of the colony by a single pair of reproductives, the so-called "king" and "queen"—has been termed "gynandrarchic," as each colony is composed of both sexes, which is diametrically opposed to the institution of colonies of the other social insects,



THE EGG-LAYING "MACHINE" WHICH IS THE QUEEN TERMITE

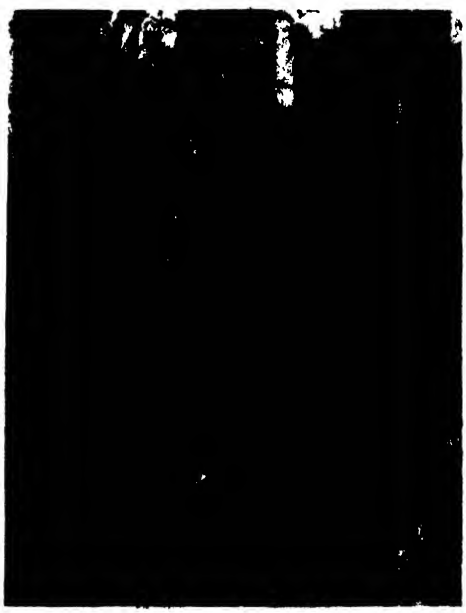
IN THE HARD SECTION OF THE TERMITARY IS A SPECIALLY CONSTRUCTED CELL INTO WHICH LEADS A LABYRINTH OF RUNWAYS. THIS IS WHERE THE REPRODUCTIVE IS HELD. AMONG THE *Nasutitermes* THERE IS USUALLY A SINGLE QUEEN WHICH OFTEN EXCEEDS THE WORKERS AND THE SOLDIERS BY AS MUCH AS TWENTY TIMES. THIS REMARKABLE PHOTOGRAPH SHOWS A QUEEN 25 MM. IN LENGTH BEING HELPED BY THE WORKERS INTO ANOTHER SECTION OF THE NEST. SUCH A REPRODUCTIVE WILL LAY AS MUCH AS THREE TO FIVE THOUSAND EGGS IN A SINGLE TWENTY FOUR HOURS.

notably the bee, wasp and ant. These hymenopterous colonies are strictly matriarchic; the male insect remains a mere episode in the life of the colony. After the female ant, for example, is fecundated, she retires alone to begin the colony without the aid of the male, who dies almost immediately after the sexual act. The impregnated female is provided with a small muscular spermatheca, or sac, for the retention of the spermatozon which was filled by the male during mating and is never renewed. The female probably has the ability to close and open this sperma-sac at will, allowing her to lay fertilized or unfertilized eggs. With the exception of the manner of reproduction, there is rather close similarity between the social structure of the ant and termite. It is really an extraordinary thing to find in nature two organisms so immensely distant in their ancestral origins and physical structures which have hit upon identical methods of elaborating a social organization, and in these two colonies we see the extraordinary phenomena of convergent evolution.

Meanwhile within the incipient termite colony, the first eggs are developing into workers: the small, delicate, transparent nymphs, as they are called, are capable of movement on hatching. Nourishment is taken from the female reproductive by ingesting the fecal contents from her anus. The growth of the worker caste, although discontinuous, is fairly rapid. By moulting or sloughing off its integument, which is a lightly pigmented exoskeleton, growth is accelerated by the insect, which increases in size with each moult.

After the final moult, when the insect reaches what is termed its "last instar," the worker takes command, if one can use such an anthropomorphic designation for the worker's activities during the expanding of the colony. It enlarges the

THE *NASUTITERMES* "QUEEN" REMOVED FROM ITS NEST WITH ITS WORKERS AND PARASITES. PLAINLY VISIBLE ON THE QUEEN'S BODY IN THE CENTER OF THE PICTURE IS A TERMITOPHILE, WHICH IS A DEGENERATED STAPHYLINID BEETLE THAT LIVES IN TERMITE NESTS.



THE REPRODUCTIVE CHAMBER OF THE CARTON-BUILDING *Nasutitermes* IS LOCATED IN THE MORE OR LESS CONCENTRIC CENTER OF THE TERMITARY. THIS SECTION, TO WHICH THE MACHETE IS POINTING, IS THE THICK WALL OF THE "QUEEN'S CHAMBER."

nest by burrowing farther into its wood-nest, if the colony is built like the diffuse (*Kalotermes*) type of nest, or it constructs in ever-growing size the large solid masonry of the termitary if it belongs to the type of termite that builds concentrated nests.

The reproductive queen, meanwhile bursting with eggs at the swelling of her ovaries, no longer feeds herself; with the male "king" (who throughout his life retains more or less his original size) she is gradually imprisoned in the expanding termite realm. Some termite queens from Africa have been collected that are as long as four inches and as thick as one's finger, lording it over all the individuals of the termitary by as much as 20,000 times their volume. Such queens, thought to be long-lived (ten to forty years), are estimated to lay as many as 6,000–7,000 eggs a day or estimated 100,000,000 eggs during their productive life; thus the termite outrivals in fecundity any other terrestrial animal.

The Soldier

To defend the termitary, the termites gradually evolved a soldier caste, a curious aberration, for its defense. In the words of M. Maeterlinck, they are "a caste of nightmarish monsters which recall the most fantastic deviltries of Hieronymus Bosch, Breughel the Elder, or Jacques Callot." Blind, apterous and, in most cases, sterile, the soldier caste has but one task—to defend the colony from the attacks of ants. Physiologically it can do little else; its mandibles are greatly elongated and not made for eating. Forged into massive crushing weapons or shaped in truncated fashion to block up the entrance to the burrowings of the colony, the mandibles are

EGG CLUSTERS AND YOUNG NYMPHS IN A NEST OF *MICROCEROTERMES* OF GUATEMALA. AFTER THE EGGS ARE FRESHLY LAID BY THE REPRODUCTIVES, THEY ARE CARRIED INTO THE HUMID SECTION NEAR THE HEART OF THE TERMITARY. THE EGGS ARE MOVED SEVERAL TIMES A DAY SO AS TO KEEP THEM IN THE WARMEST AND MOST MOIST AREA OF THE NEST. THE EGG-CLUSTERS ARE IN THE CENTER AND THE FRESHLY HATCHED WHITE NYMPHS, NEAR THE SIDE.

highly functional. In other species like the *Capritermes*, the mandibles are twisted into spring-like, snapping organs, used for tremendous nipping power and, at the same time, of utility for striking against the termitary to signal an approaching danger. The very ultimate in a soldier form is the warrior of higher termites, the *Nasutitermes* (named after the fantastic nasute soldiers) which, through a directive functionalism of the ordinary cephalic gland in the soldier's retort-like head, has been so hyper-developed that these insect soldiers can project into space thin streams of a very viscose fluid which mechanically impedes ants by quickly coagulating.

All the 1,800 species of termites have soldiers save one unique group, the *Anoplotermes* (Gr., unarmed), which has no soldier caste; the workers themselves function in an imperfect defense for the colony. All other species of termites have soldiers whose method of defense, the structure of the mandibles, are modified to fit the particular type of nest structure built by each species. None of the soldier caste are able to eat for themselves: the mandibles made for fighting, or in others reduced to functionless points, are useless for carving wood. Only the obese, blind worker with its dentated mandibles, crossing scissor fashion, is able to carve wood and pass it through its intestines. The workers eat for the whole colony, by regurgitating partially digested lignin foodstuffs into the labrum of the soldiers, the king, the queen and the young of the colony. The worker alone is capable of maintaining the colony and cultivating the fungus that some Indo-Malayan and African species nurture in their nests: so the termite worker, fragile, blind, wingless, although indefatigable, controls the whole isopteron realm through its stomach. This should be a valuable pointer for the socialist.

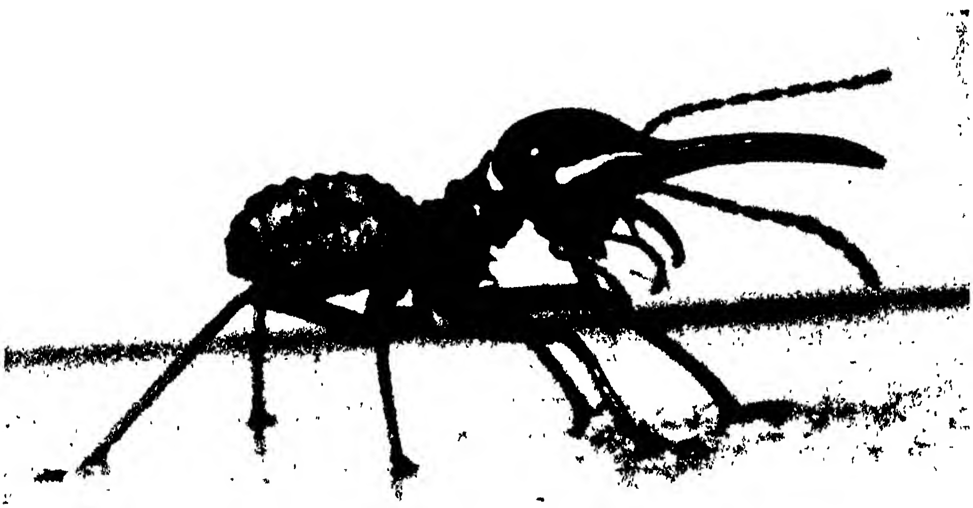
A TERMITE "QUEST"

THE TERMITOPHILE IS AN APTEROUS PARASITIC BEETLE LIVING IN INTIMATE RELATIONSHIP WITH THE TERMITES. WHILE IT OFTEN LIVES OFF THE NEWLY HATCHED BROOD OF TERMITES, IT CEMENTS ITS FRIENDSHIP WITH ITS HOSTS BY EXUDING FROM ITS ANAL EXTREMITIES A SECRETION WHICH IS EAGERLY LAPPED UP BY THE TERMITES. THIS IS A NEW SPECIES, *Eburniola gastrovittata*, COLLECTED BY THE AUTHOR.

A PLURALITY OF QUEENS

TERMITES OF DIFFERENT SPECIES VARY IN HABIT AND BEHAVIOR. IN THIS NESTING SECTION OF A LARGE NEST OF *Amitermes*, THERE ARE NUMEROUS FERTILE QUEENS. THE SMALLER TERMITES IN ATTENDANCE AROUND THEM ARE WORKERS.

A form of sexual castration is apparent in all the social insects; but the termites have worked out a method so logical in the manner in which fertility is controlled that it borders on the fantastic. If all the termites of a colony were permitted to reproduce without restraint, the population would soon outrun the available food supply. Among termites the extraordinary fertility of the queens would be such that the termitaries would develop beyond all central control. Reproduction, then, is restricted to fertile castes, while the workers and soldiers are reduced to physiological sterility. However, there is another fertile caste that is composed of potential egg-laying females who do not swarm, for their wings are only partly developed —hence they are known as brachypertous reproductive (apertous—wing, brachy—short). These castes can be developed into fertile egg-laying reproductives by a process, which is still biologically obscure. These castes supplement the original male and female reproductives. But until these supplementaries are needed they are held in check by what one eminent American termitologist believes is an "inhibiting substance" generated by the "reigning" termite queen which prevents the developement of these supplementary reproductives. Termite "queens" are well known for their exudatary secretions which are eagerly lapped up by the other members of the termitary. If the colony grows to such a point that the supplementary queens are unable to obtain any of this inhibiting substance, which chemically tends to suppress the development of their ovaries, or at least regulate and retard the appearance of the reproducing organs, the supplementaries increase until the realm becomes polyarchic. In the opinion of Dr. Emerson, there is evidence of a sort of social hormone in the termites "which influences the coordination of the parts of the society much as true hormones of our bodies are known



J. M. Leonard

A REMARKABLE PHOTOGRAPH OF A TERMITE SOLDIER

CHEMICAL WARFARE IS NOT ALONE THE INVENTION OF MAN. IN TERMITE COLONIES, A CASTE OF NEUTERS CALLED "SOLDIERS" DEFEND THE TERMITE REALM BY MEANS OF EJECTING INTO SPACE A STICKY VISCOUS SUBSTANCE FROM THE ELONGATED *nasute* OF A CAPSULE-SHAPED HEAD. THIS IS *Armitermes perarmatus* OF ECUADOR, IN ACTUAL SIZE LESS THAN 5 MM.

A MONSTER FROM THE INSECT WORLD—A SOLDIER *ARMITERMES*
KNOWN ONLY IN THE NEOTROPICAL REGION. THE REDDISH-BROWN AND STRONGLY CURVED MANDIBLES ARE USED WITH THE "NOSE" THAT PROJECTS FROM THE HEAD AS MEANS OF DEFENSE.

to produce a balance of functional relationships through their inhibiting or accelerating effect."[2]

What, then, operates this curious social organism, this symplasm of fragile, primitive, although preeminently social insect? If the king or queen are merely reproductives, imprisoned in their cells in the center of the darkness of the hypogeum, if the worker is sexless, eye-

[2] ALFRED E. EMERSON, *Natural History*, April, 1937.

LOOKING FACE TO FACE WITH A TERMITE SOLDIER
THE FRONTAL VIEW OF AN *Armitermes* SOLDIER AS AN ANT MIGHT SEE IT.

less and the soldier equally sterile, blind, even unable to eat for itself, what are the guiding factors of this organism? M. Maeterlinck, who wrote a very readable book—"The Life of the Ant"—which alas, contains vestiges of an unbridled (*unbridled*) mysticism, answers this question "easily"; the termite realm is operated by an "occult power," a "collective personality." Like his "spirit of the hive" in his "Life of the Bee," this "occult power" explanation is so removed from actual contact with reality that it explains nothing.

Naturalists have come to feel that they are dealing with nothing mystical in the termite realm. The insect, like most animal life, is composed of behavior cycles—it is part of life and as *"la vie est faite de vie rien ne vit qu'aus depens de la vie,"* termite behavior is discernible if studied minutely enough. The habits of termites are made up of "appetitive or aversive cycles" of impulses of hunger and sex (as in man), repeated ceaselessly throughout the termite's life-span, so that the whole of these appetitive cycles become very elaborate habit-patterns, which we call, for lack of a better name, "instincts."

THE STUFF OF TERMITE WARFARE
IS THIS COAGULATED LATEX-LIKE LIQUID WHICH THE *Nasutitermes* SOLDIER SECRETES FROM ITS CEPHALIC GLANDS. THE PURPOSE OF THIS DEFENSE AGAINST THE ATTACK OF ANTS IS TO CHANGE THE NEST ODOR OF THE ATTACKERS AND TO DESTROY OR LIMIT THEIR ANTENNAL SENSE.

THE RAIN-SHEDDING DEVICES
OF THIS AMAZONIC TERMITE NEST ARE THE STUDDED POINTS. OTHER SPECIES OF TERMITES USE CHEVRON-SHAPED ANGLES TO DRAIN WATER FROM THE SURFACE OF THE NEST.

These "instincts" of the termites are only observed under abnormal conditions so that this may account for much of our ignorance concerning the phases of their life cycle.

If we understand that each division within the termite colony is a specialized caste which responds through its own physical limitations or attributes to a

NASUTE SOLDIERS GATHER TO DEFEND THE REALM. A BREAK IN THE NEST BRINGS IMMEDIATE RESPONSE FROM THE SOLDIERS, WHO QUICKLY FORM ABOUT THE BREACH, THEIR HEADS POINTING OUTWARD, PREPARED FOR AN ATTACK. THE WORKERS BEGIN AT ONCE TO CARRY UP WOOD PARTICLES TO CLOSE THE BREACH.

given stimulus we may think of the entire colony as one complex socio-biological organization.

The termite organization has been successful, and it has survived for millions of years merely because of the termites' ability to temporize and to compromise with other organisms, such as the protozoa (the one-celled amoeba that is harbored in their intestines which assists in the absorption of the cellulose) and because of their ability to inhibit certain anti-social activities such as the growth of fertile supernumeraries; to suppress the extra-social activities of the aequipotential units in the interests of the whole—in short, to secure survival as a social unit through a kind of egoistic altruism. That is the triumph of the termite.

Termite Control

Control of such a complex group as the termite is not simple. Man has accentuated termite infestation by making available concentrated wooden structures, or buildings composed in part of wood over the termite's traditional habitats. By doing this, man has become an important adjunct to the termite's cellulose-cycle. Man, too, has caused the termites to spread out of their traditional habitats by the internationalization of commerce. Lumber from the United States has brought in the heartwood of Southern sugar pine a North American termite to Europe. Commerce has spread some other species through the Pacific Islands. Termites introduced to Santa Helena in 1860 destroyed more than $1,300,000 worth of property in a relatively short order. In the United States the annual damage is estimated at

A MICROSCOPIC ENGINE OF WAR

PROGRESSIVE EVOLUTION AMONG TERMITES HAS EVOLVED THE MOST FANTASTIC OF DEFENSE MECHANISMS. THE SOLDIER OF *Nasutitermes*, SO-CALLED BECAUSE OF THE LONG NASUTE OR NOSE, PROTECTS THE NEST BY EJECTING FROM THAT NOSE A STICKY VISCOUS LATEX-LIKE SUBSTANCE WHICH QUICKLY HARDENS WHEN EXPOSED TO THE AIR. IT IS GREATLY FEARED BY ANTS, FOR WHICH THIS DEFENSE HAS BEEN EVOLVED. TO GIVE SOME IDEA OF ITS SIZE, THIS TERMITE IS MOUNTED UPON THE END OF A MATCHSTICK.

$40,000,000, mostly done to outlying farm buildings where there has been figured a one per cent. damage to the $65,000,000,000 worth of farm property. The cause for this immense damage in the United States is that there are over fifty-eight species of termites found in almost every state in the Union, whereas in Europe there are found only two species of termites. As much as the British resident may grumble about the British climate, England has so far been safe from the depredations of the termite (although from the fossil records Britain had in past ages a number of termites, the island, as far as is known, is free of this destructive insect). Had England possessed a warm and equable climate, undoubtedly the termite would have taken root; for there can be no question of the fact that numerous termite colonies have been brought in from time to time in wood coming from tropical countries.

The United States being the prime sufferer from termite infestations, most of the steps for its control have originated here. In 1927 there was formed, in northern California, a "Termite Investigations Committee," which included not only large corporations with the practical problem of termite control, but also scientists from the University of California. Funds were subscribed by the oil and telephone companies, the lumber corporations and marine organizations, in fact from every big business that had a direct interest in the control of this insect. In the course of a number of years, far-flung investigations were launched under the chairmanship of Professor C. O. Kofoid, dean of the department of zoology of the University of California. Each of the two-score investigators of the problem was given a different phase of the investigation, each specialist carrying out his work in his own technological field. The habits of termites were thoroughly investigated, their manner of swarming, the study of all the appetitive cycles, in an attempt to uncover and interrupt the chain of events in the life cycle of the insect at some weak or accessible link. The association of fungus with termites, the spread of dry rot into galleries excavated and abandoned by termites, and another important matter, the types of wood relatively termite-resistant, were carefully

A CLOSE-UP OF TERMITE ARCHITECTURE
SHOWS AN EXPOSED SECTION OF WOOD CARVED OUT BY THE MANDIBLES OF THE WORKER OF THE *Heterotermes* AND RELINED AGAIN WITH WOOD-FRASS TO FORM A NEST FOR THE COLONY.

THE LESSER ANT AND TERMITE EATER, THE *TAMANDUA*

THE *Tamandua tetradactyla* HAS A LONG SNOUT LIKE A FOX AND A WORM-LIKE TONGUE, WHICH IT THRUSTS INTO TERMITES NESTS AFTER BREAKING OPEN THE CARTON WITH ITS SHARP CLAWS. THIS SPECIES OF ANT-EATER IS BOTH TERRESTRIAL AND ARBOREAL.

THE GIANT ANT-EATER OF THE AMERICAN TROPICS

A FACTOR IN THE CONTROL OF TROPICAL INSECTS IS THE ANT-BEAR, *Hyrmecophaga jubata,* WHICH DESTROYS AN INCALCULABLE AMOUNT OF TERMITES. IT HAS NO TEETH, AND THE ORAL APERTURE IS JUST LARGE ENOUGH TO PERMIT THE EXTRUSION OF A ROUND VERMIFORM TONGUE.

THE SILKY ANT-EATER, WHICH LIVES WHOLLY ON TERMITES AND ANTS

MANY MAMMALS HAVE DEGENERATED PHYSICALLY TO BECOME EXCLUSIVELY INSECTIVOROUS. ONE OF THESE IS THE SILKY ANT-EATER, *Cyclopes didactylus*, WHOSE SLIT-SHAPED MOUTH IS EQUIPPED WITH A LONG MUCOUS-COVERED TONGUE FOR LAPPING UP THE INSECTS.

scrutinized. Botanists and foresters took up the phase of the growing tree, knowing that as it is not a static organism, but a dynamic one, changing with the seasonal rhythm of metabolism and growth, to ascertain its susceptibility to attack by termites. The quantities of the movements of sap and its richness in lignin in its relation to the infestation of termites were studied and subjected to experimentation. Commercial organizations experimenting with the impregnation of woods, chemicalized woods, were invited to submit samples of chemically impregnated wood to the investigation committee. In turn, these were submitted to long-range tests in the tropics as well as in the temperate zones to ascertain in each particular sample, first, its comparative immunity from termite attack and, second, to discover whether or not the chemicals with which it was impregnated would leach out under the soil.

So it went on: every termite problem tested, perfected, experimented with, until the final reports of this vast experimentation were placed in the hands of the university printer.

From the California press in 1934 came a seven-hundred page volume, "Termites and Termite Control," embodying contributions from the specialists in all the technical fields that the termite entered when it began to carve away man's buildings. It is the most complete volume on the subject; in several fields it is exhaustive and, what is more, a noteworthy monument to the necessary synthetization of objective "big business" and "subjective" science.

The book contains no one panacea. The investigators realized that they were dealing with, if not a sagacious animal, at least an insect that intuitively adjusts itself quickly to changing conditions.

A social organization before the Age

of Reptiles, the termite colony has lived through the cataclysmal changes that have come over the world and has survived when most of the other contemporary inhabitants of that period perished. It was content to live on natural plants until man placed his houses over the parts where the vegetation had grown, so it readily adapted itself to that "sapient" structure. While the most unanthropomorphic naturalist might readily admit that termites possess powers and senses of which we have only a rudimentary knowledge, and that these senses render unnecessary the multitude of auxiliary appliances indispensable to our form of civilization, he would insist that the social insects, despite the perfection of their society, differ mostly from—and are grossly inferior to—man in their not having learned the use of tools.

Man, too, would have remained in the primitive anthropoidal stage if he had not learned the use of tools by which he could add to (even if he does periodically destroy certain phases of it) a cumulative culture. Although termites should have grown wiser by the numbers of libraries they have consumed, there is little evidence of their bequeathing bank accounts to libraries or other public institutions, a seemingly important corollary in advancing the mores of society.

We are told by spectacular writers that soon we are to enter into the Age of Insects and that the termites will play a fantastic part in that insectivorous dominance. But I doubt it, if for no other reason than the actual structure of the insect. Julian Huxley recently wrote an essay on the "Uniqueness of Man"; in it he has something to say about the evolution of insects:

> The breathing mechanism has cut off insects from making great progress. The land arthropods adopted methods of air tubes or tracheae branching to microscopic size and conveying gases directly to and from the tissues instead of using dual mechanisms of lungs and bloodstream. Laws of gaseous diffusion are such that respiration by tracheae is extremely efficient for very small animals, but becomes rapidly less efficient with increase of size, until it ceases to be of use at a bulk below that of a house mouse. It is for this reason that no insect has become moderately large by vertebrate standards or moderately intelligent.

And this limitation of insects applies equally well to the termite, or white ant.

SAVING THE PAST FOR THE FUTURE

HUMAN lives are not the only casualties in war. Cherished wherever civilization has existed are the irreplaceable relics of the past--buildings, monuments, books and manuscripts. Nowhere is that store richer or in greater danger than in England. Already destruction has been extensive. Many noble buildings are rubble and many unique records have been destroyed. At the University of London, to take one instance, the Egyptology collection was badly damaged by water, the Mocatta Library and collection of Anglo-Judaica were shattered by incendiary bombs and over 100,000 books were consumed in the fire. Other libraries, too, have been destroyed, involving the loss of thousands of books. There are no duplicates of much of this material; it can never be replaced. Fortunately, however, most of the valuable records of England are still unharmed. In the hope of preserving for the future the substance of this universal heritage, and of making it available to scholars everywhere, the Foundation, in 1941, appropriated funds for two emergency projects for copying and recording important historical, literary and architectural treasures.—*Raymond B. Fosdick in "The Rockefeller Foundation Review for 1941."*

SOIL EROSION AS AN ECOLOGICAL PROCESS

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WITH respect to their influence upon habitat there is a significant difference between normal or geological erosion and man-made or accelerated soil removal. Erosion induced by man may cause unusually rapid and profound changes in environment; furthermore, it is now so wide-spread throughout the world that it critically reflects itself in the social and economic welfare of nations. Although much has been written within the past decade about the influence of vegetation upon run-off and erosion, scant literature has appeared relating to the opposite effect; that is, the influence of erosion upon plants and animals. It is the purpose of this paper to note something of the influence and importance of man-induced soil erosion as a process affecting the habitat. Attention will be directed to differences between undisturbed and eroded soils, and to ways in which accelerated erosion affects living things.

Although it is a significant and wide-spread phenomenon, man-induced soil erosion has been much neglected by ecologists. Although grazing, lumbering and fire due to the activities of man have long been recognized as environmental influences, practically no text-books on ecology have considered accelerated soil erosion as an important ecological process. This disregard is also well illustrated by the fact that until a few years ago many extensive agricultural field investigations were conducted with careful consideration of climatic factors, application of fertilizer and crop yields, but with no consideration of erosion, which in many instances was removing soil from the land on which the experiments were being conducted at a rate sufficient to invalidate the results of the investigations.

Recent theories of soil genesis acknowledge five influences in the production of natural soils; namely, climate, native vegetation, underlying rocks, relief or slope and age. That soil is the result of the dependent interaction of these several factors replaces the older idea that soil is simply decomposed rock—a result of destructive weathering—or that it results entirely from vegetation. Such modern concept greatly influences one's thinking with regard to accelerated erosion, for if soil were only decomposed rock or consisted simply of vegetative remains, soil removal would be a less serious matter than it is. A given soil type, therefore, is the result of continued interaction of several processes, including the physical disintegration and chemical decomposition of mineral constituents and the recombination of some of the resulting substances. Such substances, together with organic materials composed of plant and animal residues, are being constantly redistributed as a consequence of water movement, leaching and the activities of the soil microflora, microfauna and, to a lesser extent, larger animals such as earthworms and burrowing rodents. These physical, chemical and biological processes normally maintain a soil profile of definite depth and composition, usually of three well-defined yet genetically related horizontal layers, the A, B and C horizons (Fig. 1). The A horizon is popularly called topsoil, the B, subsoil. Together they constitute the solum, or true soil. Below them is the C horizon consisting of parent material that is weathered but still unchanged by

other soil-building processes. Underlying the C horizon is the unweathered and completely unchanged parent material.

In very broad terms, it may be said that normal erosion, a process as old as geological history, is in most regions of the world an imperceptibly slow, although persistent action. It is usually so gradual that as upper portions of the soil profile are removed by wind or water, soil-building processes replace them and develop the lower portions to compensate for the removal. The result is the gradual downward progress of the entire profile and, geologically, eventual leveling of the landscape or peneplanation. The first effect of man-induced erosion is the removal of portions of the A horizon at a rate faster than formative processes can replace them—an effect evidenced by sheet erosion and the formation of rills (Fig. 2). If the process continues, sheet erosion may be followed by the removal of portions of the B horizon and the development of gullies. Gullies may erode into the C horizon and are known in many instances to have cut below it to remove portions of the parent material also (Fig. 3). The loss of soil by such process is, on land under human occupations, serious and costly and not easily amended by the application of fertilizer or improved soil-management practices.

Physical and Chemical Conditions

Soil science has demonstrated great differences in the physical condition of various soils attributable to texture, content of organic matter, character of colloids, porosity and content of water and gases. Even a superficial knowledge of the nature of soil profiles, however, indicates that there may be less variation in the physical condition of the A horizons of different soil types than there is between A and B horizons of the same soil profile.

In general, at least during the growing season, soil temperature decreases with depth of soil. Likewise lower horizons of an undisturbed soil frequently have lower water and air capacities than the surface layer. A definite relationship exists between available water and the physical structure of the soil, and it is known that infiltration rates vary greatly for different soil types and for different horizons of the same soil. When the topsoil with its porous structure is removed by erosion, the temperature, water-holding capacity and other physical features of the exposed substratum are, therefore, markedly different from those of the undisturbed soil.

Experiments have shown that muddy suspensions percolate through soil col-

PROFILES OF THREE SOIL GROUPS

(DIAGRAMMATIC)

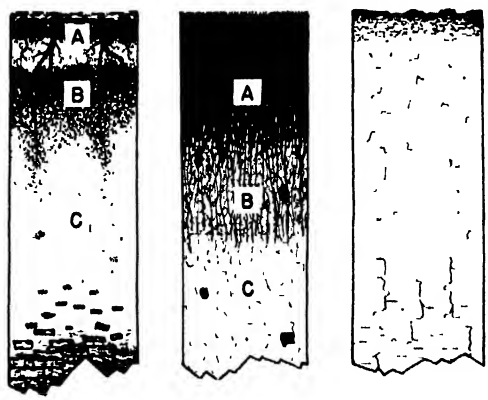


FIG. 1. PROFILES OF SOIL GROUPS

PODZOL, CHERNOZEM AND RED DESERT. THESE PROFILES CHARACTERIZE SOILS DEVELOPED RESPECTIVELY UNDER FOREST, GRASSLAND AND DESERT CONDITIONS. NOTE THAT THE A, B AND C HORIZONS OF THE PODZOL DIFFER IN THICKNESS AND COMPOSITION FROM COMPARABLE HORIZONS IN THE CHERNOZEM, AND THAT THE RED DESERT SOIL IS WITHOUT DISTINCT HORIZONS. THERE IS FREQUENTLY GREATER PHYSICO-CHEMICAL AND BIOLOGICAL DIFFERENCE BETWEEN THE A HORIZON OF A VIRGIN SOIL AND ITS RELATED LOWER HORIZONS THAN THERE IS BETWEEN THE A HORIZONS OF DIFFERENT SOIL TYPES DEVELOPED UNDER TOTALLY DIFFERENT CLIMATES.

umns at about one tenth the rate of clear water. Concerning this relationship Bennett[1] has said that a natural cover of vegetation "prevents the formation of soil suspensions by rainwater at the surface; the water remains clear, and the rate of intake is maintained at the natural capacity of the soil profile. But bare soil surfaces produce muddy suspensions under the impact of rain, and such suspensions . . . tend to seal off the surface, thereby reducing the rate of intake of water into the soil." Here then is one reason why the destructive aspects of accelerated soil erosion are cumulative, for, within limits, the more silt suspended the higher the run-off, and the higher the run-off the greater the power of water to erode the soil.

Although it is recognized that organic matter can not be expressed exactly by the carbon-nitrogen ratio, a figure denoting the proportion of carbon to nitrogen in the soil is nevertheless a useful indicator of soil organic matter. Even for such divergent soil groups as Chernozems, Podzols and Laterites (Fig. 1), there is known to be a steady decrease of the carbon-nitrogen ratio with depth. The ratio in the A horizons is higher than in related B horizons and for each soil group the ratio in the B horizon usually averages higher than in the underlying C horizon. A recent study of several important agricultural soils from various parts of the United States, for example, showed that organic matter averaged a drop from 4.3 per cent. in topsoils of virgin or slightly eroded condition to 1.0 per cent. in erosion-exposed subsoils of corresponding types nearby. As far as organic matter is concerned

[1] H. H. Bennett, "Soil Conservation," p. 206. New York and London, 993 pp., 1939.

FIG. 2. SHEET EROSION IN A CALIFORNIA GRAIN FIELD

SHEET OR RILL EROSION FREQUENTLY CHARACTERIZES THE REMOVAL OF THE A HORIZON OF THE SOIL PROFILE. INCIPIENT GULLIES INDICATE A TRANSITION TO A MORE SEVERELY ERODED CONDITION.

FIG. 3. MISSOURI GULLIES THAT CUT THROUGH THE SOIL PROFILE DEEP INTO THE PARENT MATERIAL. FOLLOWING THE REMOVAL OF THE *A* HORIZON, EROSION INTO LOWER HORIZONS INCREASES, EVEN TO THE EXTENT OF CAUSING A COMPLETE CHANGE OF LANDSCAPE.

the different horizons of the same soil may be considered as distinct as the surface layers of different soils developed under different climatic conditions.

It is likewise recognized that amounts of essential elements vary with depth of soil. As a general rule, the content of nitrogen in soils is greatest in the plow level and decreases with depth; this is like the change with respect to organic matter. That phosphorus near the surface may be most available to plants is also indicated by experiments which show that in the surface of many soils approximately one third of the phosphorus present is in organic combinations, while in subsoil only about one fifth of the total phosphorus is in such available form. The potash (K_2O) content of soils may not display such a general correlation with soil depth, but the potassium cycle is a relatively simple one with no great quantities accumulating, as with nitrogen in proteins or phosphorus in bones, and because potassium remains essentially soluble its waste by soil erosion can be particularly significant. The hydrogen-ion concentration also varies with soil depth.

Although it is recognized that deficiency of a chemical element may limit the growth of a plant species, too much importance should not be attached to single elements or isolated characteristics of the soil as habitat factors. Together, however, physical and chemical properties of soils combine to establish the soil as a habitat entity, and inorganic constituents of the soil can be sufficiently changed by accelerated erosion to produce a soil and habitat condition different from that existing on the same site before such erosion occurred.

Soil Biota

In addition to physical and chemical changes in the soil induced by erosion, there are comparable changes in the soil

biota. Normal habitats for shrews, moles, burrowing rodents and other vertebrates are materially altered by man-induced soil removal, but it is undoubtedly upon invertebrates and the microbiota of the soil that erosion has the greatest effect. It has long been known that the numbers of bacteria in humid regions decrease with depth of soil. There is a corresponding correlation between soil actinomyces and soil depth and it has also been demonstrated that soil protozoans may be practically confined to the uppermost few inches of soil.

Experiments have disclosed some interesting relationships between the normal microflora of a given soil and the number of microorganisms to be found in the eroded material from that soil. Expressed as numbers in each gram of dry solids, the average total number of microorganisms in run-off is known in some instances to exceed that in the original soil by about 200 times. The organisms are either adsorbed by the soil particles or suspended in the transported materials, and their removal demonstrates the great reduction of soil microorganisms which accompanies the loss of soil particles by erosion.

Jacot[2] has emphasized the great importance of microarthropods in maintaining normal soil structure and states that the depth to which such a fauna penetrates is probably equivalent to the depth of root penetration. His investigations of various soils in North Carolina show reduced populations of these small arthropods with increase in soil depth. For example, 2,800 saprophytic mites per square foot were counted in the top 3 inches of soil, while 10 to 13 inches below the surface only 28 of these organisms occurred. Likewise the number of saprophytic insects and myriapods dwindled from 500 per square foot 1 to 3 inches below the surface to 22 at a depth of 10 to 13 inches. Such studies also demonstrate that soil erosion eliminates the porous channeled layer in which microarthropods are most abundant, and that repopulation of abandoned agricultural land by these organisms is very slow. The soil microbiota is inextricably associated with the maintenance of normal soil structure, and because it is most extensive in the A horizon and less well represented at greater depths, the removal of the upper parts of the soil profile results in the loss of most of these very valuable organisms.

Crop Yields

The most convenient biological index of the effect of accelerated erosion is the growth of higher plants. Plant growth indicates this effect by crop yields produced respectively on A and B horizons of the same soil type, and by the vegetation naturally occupying eroded areas. Recent experiments by the Soil Conservation Service reveal that on 10 representative types of farm land under comparable conditions of slope, rainfall and cultural treatment, the per acre yield of several agricultural crops on subsoils was materially less than the yield produced on topsoils of the same soil types. Latham[3] has recently compared the productivity of the A horizon of Cecil sandy loam with that of the B and C horizons exposed by erosion, as determined by the yield of seed cotton produced in experimental plots. Under the conditions of the experiment the A horizon proved more than three times as productive as the B and eleven times as productive as the C horizon.

Furthermore, the rate of erosion usually is not retarded when the topsoil is removed, but may then increase to cut downward into the parent material which in almost all cases is less productive than any of the layers above it.

[2] Arthur P. Jacot, *Ecology*, 17: 359–379, 1936.

[3] Earle E. Latham, *Jour. Am. Soc. Agron.*, 32: 950–953, 1940.

Even with heavy application of fertilizer it is generally impossible to bring the yield from subsoil up to that from the related surface soil, so great is the difference in their composition. This difference is important, for in spite of higher quality seed, more productive varieties of crop plants, better fertilizers and improved cultural practices, the average per acre yield of cotton for the United States has declined materially, corn has not quite held its own, and even the yield of wheat has increased but slightly.

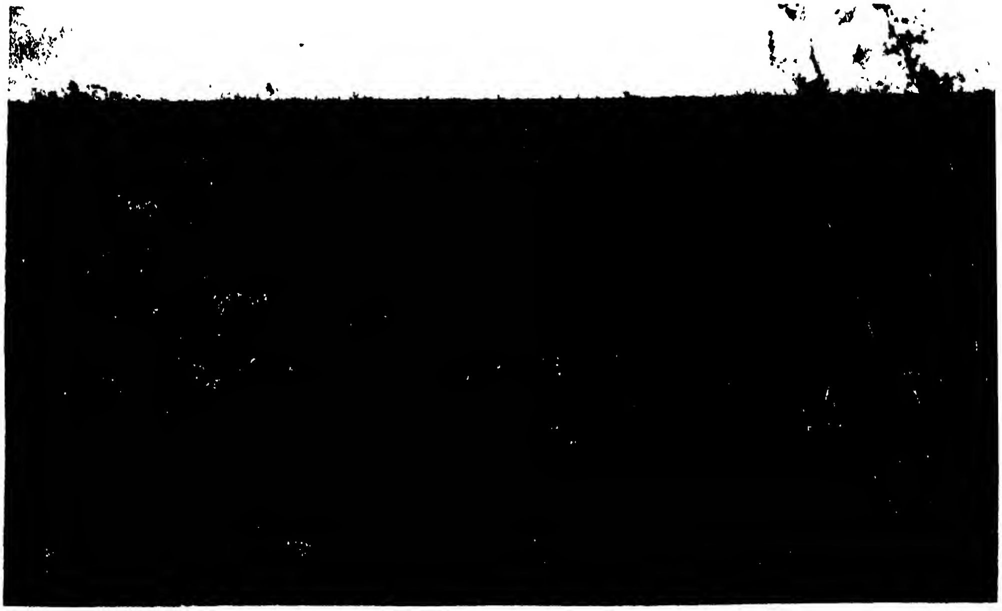
Of course, the reasons for such decline can not be easily assigned. Increased use of farm machinery during the past several decades has emphasized greater production at the expense of acreage yield, and the extension of agriculture into regions less suitable to major crops has also tended to reduce production per acre. There is considerable evidence to indicate, however, that accelerated soil erosion is a factor that has contributed importantly to the limitation of crop yields on agricultural lands.

Native Vegetation

But the ecologist need not look to agricultural statistics alone for the effects of humanly provoked erosion. In studies of the establishment and succession of vegetation on different soil horizons, Sinclair and Sampson[4] experimentally demonstrated that on certain California soils the amount of plant material produced and the growth rate of both annual and perennial wild plants were appreciably greater in soil horizon A than in lower horizons. For example, in Holland soil, the growth of *Stipa pulchra*, a climax species, at maturity in horizon B was 23.88 per cent., and in horizon C, 20.63 per cent., of the growth in horizon A. Flowers bloomed earlier on plants growing in the A horizon, while on B and C horizons perennial

[4] J. D. Sinclair and A. W. Sampson, *Hilgardia*, 5: 155–174, 1931.

FIG. 4. SEVERELY ERODED AREA IN THE APPALACHIAN PIEDMONT OF NORTH CAROLINA. SHORTLEAF PINE (*Pinus echinata*) IS INVADING THE ERODED SITE WITHOUT THE CONDITIONING OF HERBACEOUS PLANTS THAT USUALLY PRECEDES THE WOODY VEGETATION.



H. L. Shantz

FIG. 5. DESERT SHRUB IN THE SOUTHWESTERN UNITED STATES
WHERE CREOSOTE BUSH (*Larrea tridentata*), A COMPONENT OF THE NATURAL VEGETATION, MAY IMMEDIATELY REPOPULATE AN AREA AFTER IT HAS BEEN DISTURBED.

FIG. 6. SILT DEPOSIT ALONG A STREAM IN TENNESSEE
DEPOSITION OF EROSION SEDIMENT ALTERS STREAMS AND PONDS AS HABITATS FOR AQUATIC LIFE.

species produced practically no seed. The growth of non-climax weed species, however, showed comparatively slight differences when grown on the various soil horizons. In these experiments the water requirements of plants were shown in all cases to be higher in horizon C and in most cases in horizon B, than in the A horizon. This fact emphasizes the deficiencies that eroded soils may create in the plant habitat, for, as already pointed out, the rate of percolation of muddy water is only a fraction of that of clear water. Thus in eroded soils water requirements of plants are particularly high where available water is comparatively low.

Range type and degree of erosion on the Boise River watershed have been related by Renner,[5] who pointed out that the range with the most gullies was populated with a weed community representing an early successional stage. Studies also show correlations between accelerated soil erosion and vegetation in which both the forage density and vegetation density vary inversely with the degree of erosion, while the deterioration in plant cover increases as erosion becomes more severe. Others have touched upon this relationship, including Bennett,[6] who has described in general terms some of the types of vegetation inhabiting eroded areas throughout the United States.

Succession

Recent studies have demonstrated a definite relationship between the stages of plant succession and soil erosion, and variations in biotic communities under different types of land use have been described. Related changes of physiography and of animal populations, including various groups of insects, birds and mammals, have also been correlated with intensity of accelerated erosion.[7] More studies of this type are needed, for they may aid in revising some ecological concepts. Perhaps more important, they can be of value in the development of sound land use practices which in many instances are of necessity based upon insufficient and inadequate data.

One can not observe serious erosion, especially as it exists in the Appalachian Piedmont, without wondering if we do not need some adjustment of our theories about plant succession. Many bare areas caused by soil erosion remain free of expected pioneer species for many years —possibly as long as the existing rate of accelerated erosion persists. Frequently, when invasion does occur on eroded soils in the Piedmont, it does not start with herbaceous stages and proceed from annuals to perennials, to broomsedge (*Andropogon virginicus*), to pine, as the theory of secondary succession academically demands. Instead, loblolly or shortleaf pines may invade a highly eroded cultivated field soon after it is abandoned. Where seeds are available, the immediate development of a stand of pines seems to exclude or perhaps, telescope, all the earlier successional stages. On severely eroded soils the invasion of pines apparently does not require conditioning by weeds and other herbaceous plants that usually precedes the establishment of pines under other circumstances (Fig. 4). This direct progression from bare area to pine forest is one scarcely consistent with a rigid interpretation of most concepts of plant succession.

Concepts of succession have, for the most part, been developed by ecologists dealing with vegetation of humid regions. It now appears that such concepts must be modified, particularly with respect to the changes of vegeta-

[5] F. G. Renner, *U. S. Dept. Agr. Tech. Bull.*, 528, 32 pp., 1936.

[6] H. H. Bennett, SCI. MONTHLY, 35: 385–415, 1932.

[7] Charles Clinton Smith, *Ecol. Monographs*, 10: 421–484, 1940.

tion in arid areas. In parts of Mexico and the arid southwestern United States desert shrubs are dominant components of the original, undisturbed vegetation (Fig. 5). There is reason to believe that when this natural, or climax, vegetation is disturbed, these same shrubs and associated species immediately repopulate the area, and that there occur none of the stages of vegetation usually believed to precede the reestablishment of a climax type. It is of interest to note that in this region soil groups such as the Red Desert soils of the Mohave and other American deserts are wholly different from either forest or true grassland soils, for they are without distinct A, B and C horizons (Fig. 1). Furthermore, there may be considerable significance in the fact that the invasion behavior of pines in the Appalachian Piedmont is comparable in principle to that of the direct reestablishment of climax shrubs in desert areas. The way in which Piedmont pines populate old fields may indicate a reaction to a desert-like soil profile developed on severely eroded sites. It is possible, therefore, that accelerated erosion may so alter soil conditions, even under a prevailingly humid climate, as to create, at least for a time, what amounts to a sub-humid environment. Thus, so far as a habitat factor is concerned, highly eroded phases of soils originally developed under humid climates may be considered somewhat analogous to uneroded soils developed under desert conditions.

Aquatic Habitats

The effect of erosion upon the environment is not limited to land habitats. Its influence upon aquatic habitats may be very great, for the waters of ponds, lakes and streams have been seriously modified by siltation, and sedimentation studies stress the rapidity with which reservoirs are being filled with silt and erosional debris (Fig. 6). It is well known that when erosion fills pools with sediment or, by removing vegetation along the banks, permits the water temperature to rise, it can convert a stream once ideally adapted to trout into an environment totally unfit for such species of fish.

Much has been written about stream pollution by industrial wastes, but not much inquiry has been directed toward the damage caused by suspended soil which, however, is even more common and very probably more important as an influence upon aquatic organisms. Studies of erosion silt as a factor in aquatic environments indicate that it is a highly significant influence. Ellis[8] states that

> erosion silt and other suspensoids (disregarding any specific toxic action of suspensoid wastes) affect fisheries directly by covering the bottom of the stream with a blanket of material which kills out the bottom fauna, greatly reduces the available food, and covers nests and spawning grounds; . . . the mechanical and abrasive action of the silt itself . . . may clog and otherwise injure the gills and respiratory structures of various aquatic forms, including many fishes and mollusks. . . . Indirectly, but none the less effectively, erosion silt affects fisheries by screening out the light, by "laking down" organic wastes, and thus increasing the oxygen demand at the bottom of the stream, and by retaining many forms of industrial effluents, as oils, chemical wastes, and pulps in beds on the floor of the stream, with disastrous results to the bottom fauna.

A factor so distinctly affecting aquatic habitats must determine the existence not only of specific organisms but of aquatic plant and animal associations and their successional relationships as well. Two main successional trends of aquatic plant associations have been distinguished in English lakes, depending upon the presence or absence of silting by inorganic material. Studies of community relationships in aquatic environments as related to degree of siltation in the United States, however, have been almost neglected. Nevertheless, the evi-

[8] M. M. Ellis, *U. S. Dept. Commerce, Bull. Bur. Fisheries*, 48: 365–437, 1937.

dence at hand suggests that man-induced soil erosion may critically influence aquatic environments just as it does terrestrial habitats.

Conclusion

In summary, it may be said that accelerated soil erosion is considered an important ecological process because it produces marked changes in both the inorganic and biologic components of the environment due largely to removal of portions of the soil profile. Through such erosion, water infiltration is lessened, organic matter is reduced, and the chemical composition of the soil is materially altered as shown by depletion of nitrogen, phosphorus and available potash. Biologic changes are shown by a greatly reduced soil biota, especially bacteria, actinomyces, protozoa and microarthropods, which are normally most numerous in the uppermost layers of the soil. Higher plants indicate even more conspicuously the effects of man-induced erosion, as shown by experiments in which crop yields from undisturbed soils prove materially higher than yields from eroded phases of the same soil types; wild plant growth shows a similar correlation. Successional stages of native vegetation may in some instances be related directly to degree of erosion and it is suggested that further study of the invasion of eroded areas might result in revision of some ecological concepts. The effect of erosion is likewise evident in lakes and streams where silt alters aquatic populations and their successional behavior. The inorganic and biologic changes resulting from accelerated erosion and the extent of eroded land combine to make highly important the relation of soil erosion to habitat.

It is difficult to assign environmental equivalents to soil profiles or horizons, but it seems that there may be as much difference between the A horizon of a virgin soil and its related lower horizons exposed by erosion as there is between the A horizons of different soil types developed under totally different climates. Accelerated soil erosion, therefore, may minimize the effects of other environmental elements, such as physiography, precipitation, temperature and length of growing season. Inasmuch as the ecological importance of man-induced soil erosion may be as great as that of climatic influences, it would be of value to the ecologist to examine erosion more closely with respect to its effect upon plant and animal populations. The results of such investigations would be of considerable academic interest and would contribute to knowledge of ecological principles applicable to the revegetation of eroded areas and to the management of crops, pastures, woodlands and wildlife wherever such management is undertaken as part of a program for the conservation of soil and soil resources.

STEPHEN HALES—PIONEER PLANT PHYSIOLOGIST

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DURING the seventeenth and eighteenth centuries, when the followers of Francis Bacon were supplementing the deductive logic of the Greeks with experimentation and inductive reasoning and thereby giving birth to modern science, it was not uncommon for men who were scientists by avocation to make important scientific contributions. Although we may have been surprised to learn that Christopher Wren (1632–1723) was not only one of the greatest of architects, but also made valuable contributions to mathematics and science,[1] we all know that Benjamin Franklin (1706–1790) added to our knowledge of electricity, that Joseph Priestley (1733–1804), who discovered oxygen, was a nonconformist minister, and that Gilbert White (1720–1793) was curate of Selborne when he wrote its natural history.

Not so generally known is the fact that another English clergyman by the name of Stephen Hales was virtually the founder of the science of plant physiology, contributed much to the field of animal physiology, and was in addition something of a chemist and inventor. Stephen Hales has not been forgotten: almost every history of botany or biology at least mentions him; he has been the subject of an excellent book-length biography,[2] and the American Society of Plant Physiologists has named a prize award in his honor. However, among scientists in general and the educated public as a whole he is not well enough known. To fully appreciate the quality and importance of his work we must refresh our minds on the state of science about the time of his birth in 1677 at Bekesbourne, Kent.

Physics was becoming an exact science, due primarily to the work of Galileo, who not only studied the motion of falling bodies, stated the laws of dynamics, and helped create the science of astronomy, but is also often regarded as the founder of the experimental method. Newton published his famous "Principia" in 1687 when Hales was ten, and he dominated English science at the time Hales was receiving his education.

Chemistry had developed little beyond the flounderings of the alchemists. One of the few contributions of permanent value to the science made during Hales's time or before was Boyle's work on the gas laws (1660) and his discovery that air is necessary for life and combustion. Although Hales lived during the days of the phlogiston theory, it is interesting to note that he did not accept it, but belonged to Boyle's chemical school. To understand how little chemistry had developed by Hales's time, it is necessary only to mention that not a single chemical element had been discovered, and chemical equations were of course unknown. The true founders of modern chemistry—Black, Cavendish, Priestley, Scheele, Lavoisier—were all born at about the time of Hales's zenith, and he lived to see only Black's discovery of carbon dioxide. At Hales's time the old

[1] Dorothy Stimson, "Christopher Wren, F.R.S.," SCIENTIFIC MONTHLY, 53: 360–367, October, 1941.

[2] A. E. Clark-Kennedy, "Stephen Hales, An Eighteenth Century Biography," Cambridge University Press, 1929. The quotations from Stephen Hales and his contemporaries given here are taken from this volume.

Greek idea that all was earth, air, fire or water had been modified only to state that "earth" consisted of various mixtures of salt, mercury and sulfur.

Most of the biological concepts of the time were based on the teachings of Aristotle and the other Greek philosophers, although human anatomy had made great progress through the work of Vesalius and others. In 1616 modern human and animal physiology was set on its way by the discovery of the circulation of blood by William Harvey. Botany had advanced but little beyond Theophrastus, until the appearance of Hales's immediate predecessors: Grew, Malpighi, and Ray. Malpighi and Grew simultaneously laid a firm foundation for plant anatomy in 1671, and Ray's "Historia plantarum generalis," published in 1686, was an important milestone in taxonomy. Linnaeus was a contemporary of Hales, though he published his works a decade or more after Hales's "Vegetable Staticks" appeared.

The concepts of plant physiology as late as the seventeenth century were still based on the ancient speculations of Aristotle: that food for plants was prepared and elaborated in the earth for them, different food being prepared for each species, and that actual nutrition was controlled by a soul, probably located in the pith. Jung and Van Helmont objected to some of Aristotle's theories, but, as Sachs expresses it, "their objections remained sterile and unproductive." Ray dabbled with physiological experiments, but his methods were crude, his apparatus inadequate, and he contributed nothing of importance. While Grew and Malpighi were laying the foundations of anatomy they had the solution of physiological problems constantly in mind. However, they based their conclusions on vague theorizing rather than on experimentation, and it is hardly surprising that most of their concepts were extremely fanciful. Following Harvey's demonstration of the circulation of blood in 1616 many attempts were made to demonstrate it in plants, and it was generally assumed that circulation existed in plants, until the theory was finally disproved by Hales. Sachs summarizes the early history of plant physiology as follows:

"If we compare what was known before Malpighi's time with the contents of Hales's book ("Vegetable Staticks"), we shall be astonished at the rapid advance made in less than sixty years, while scarcely anything had been contributed to the subject in the period between Aristotle and Malpighi."[3] We may add that practically all the advance may be attributed to Hales himself.

Stephen Hales's family was one of the oldest and most distinguished in Kent. When Stephen was only a boy his father died, and Stephen was brought up by his grandfather, Sir Robert Hales. In 1696 he entered Corpus Christi College, Cambridge, from which he received his A.B. in 1699. He continued his studies and secured his M.A. degree in 1703. The same year he was elected a fellow of the college. Up to this time his work had been largely in the field of theology, although it seems that he had developed quite an interest in physical science, probably due to the influence of Sir Isaac Newton, "the shining light of Trinity."

However, he did not develop a serious interest in science until the early years of his fellowship. While the stimulation of his interest in physical science may be attributed to Newton, his interest in biology must be attributed to William Stukeley, several years his junior and an undergraduate at the time Hales was a fellow. They struck a close friendship, as indicated by the following account by their contemporary, Peter Collinson:

> They rambled over Gogmagog Hills and the bogs of Cherry-Hunt-Moor to gather simples

[3] Julius von Sachs, "History of Botany," Oxford, 1906.

with Ray's "Catalogus Plantarum circa Cantebrigiam nascentium" in their pockets, to which Stukeley, who was always a ready draughtsman, had added a map of the country, the better to direct them in their peregrinations; in some of these expeditions they collected fossils from the gravel and chalk pits; and in others they hunted butterflies, having contrived an instrument for taking them. Hales also in conjunction with his friend Stukeley applied himself to the study of anatomy, frequently dissecting frogs, and other animals, in their herbalizing walks. They proceeded also to the dissection of dogs, and Hales contrived a method of obtaining a preparation of the lungs in lead, of which Dr. Stukeley now has several specimens. They applied themselves also to chymistry and repeated many of Mr. Boyle's experiments, making flowers of benzoin, pulvis fulminanus, elixir proprietatis, and various preparations, some of use and others of curiosity: but besides what they did between them, they attended the chymical lectures that were then read by the public Professor Signoir Vigani in Queens College Cloysters, and went also to see the chymical operations which he performed in a room at Trinity College, which had been the laboratory of Sir Isaac Newton, and in which, unfortunately for the world, Sir Isaac Newton's manuscript concerning chymical principles was accidentally burned.[4]

In 1708 Hales became perpetual curate of Teddington, an attractive country village of less than five hundred population on the north bank of the Thames, fifteen miles up from London. However, he did not vacate his fellowship at Cambridge until 1718, when he also became rector of Porlock. In the meantime he had taken his B.D. degree at Cambridge and had kept in close contact with the university. He held his position at Porlock only four years, resigning to become rector of the more accessible village of Farringdon, a position which he held, along with his curateship at Teddington, until the time of his death. At that time it was customary for the better educated ministers to have several parishes and to employ less well-educated curates to take care of the smaller ones. Hales maintained his residence at Teddington, visiting Farringdon for only a month or two each summer.

[4] Peter Collinson, *Gentleman's Magazine*, 34: 273, 1764.

Shortly after Hales went to Teddington, he began his first important scientific research by experimenting on blood circulation in dogs and horses. He started out to find whether there was any truth in the current theory that the pressure of the blood in the muscles was great enough to account for muscular action. He finally disproved this theory, but in the meantime he made many other important discoveries concerning circulation. Some of his experimental methods were dramatic. He would strap down his dogs or horses, and without anesthesia (which was then yet undiscovered), he would insert a glass tube as much as thirteen feet long in various large arteries and veins and then measure the height to which the blood was forced. Garbled accounts of his experiments got around the neighborhood and there was a certain amount of objection to his work. His neighbor and good friend, Alexander Pope, had this to say:

> I shall be very glad to see Dr. Hales and always love to see him, he is so worthy and good a man. Yes, he is a very good man, only I'm sorry his hands are so much imbued in blood. . . . Indeed he commits most of these banalities with the thought of being of use to man. But how do we know that we have a right to kill creatures that we are so little above us as dogs, for our curiosity.

Hales's experiments also figured in a poetic account of a trip up the Thames, entitled "The Boat," and written by a Reverend Thomas Twining:

> Green Teddington's serene retreat
> For philosophic studies meet,
> Where the good pastor Stephen Hales
> Weighed moisture in a pair of scales,
> To living death put mares and dogs,
> And stripped the skins from living frogs.
> Nature he loved, her works intent
> To search or sometimes to torment.

A mere listing of his contributions will make us realize that whatever sufferings his experimental animals endured were not in vain. He found out that the pulse rate was greater in small animals than large ones, that blood pressure was

greater in large animals than small ones, that there was less resistance and pressure in the pulmonary than the systemic circulation and that certain saline solutions would prevent clotting. He made accurate measurements of blood pressure under various conditions, and determined the capacity of the heart, the diameter of blood vessels and the rate of flow of blood in the capillaries of the frog. He measured the pressures necessary to burst various arteries and veins. He was not satisfied with the current concept that the heat of the body was due to the friction of the blood in the capillaries, and had chemistry been as advanced as physics at the time he might have discovered the true cause. He demonstrated spinal reflexes in frogs long before the nature of nerve action was understood, and discovered that bone growth is at the symphyses, a contribution usually falsely attributed to John Hunter. He speculated that the animal spirits, as nerve impulses were then called, might be due to electrical charges. He had a remarkably clear insight into the nature of secretion. Later in life he did some important work in animal respiration, even conducting experiments on himself. Hales was a competent animal physiologist, and even if he had done no work at all in botany his name would still figure in the history of science. The writer in the "Dictionary of National Biography" claims that, "In first opening the way to a correct appreciation of blood pressure, Hales's work may rank second in importance to Harvey's in founding the modern science of physiology."

His work on circulation was not published until 1732, when it appeared in the form of a book entitled "Haemostaticks." Some twenty years had elapsed since he had done most of his research in this field. In the meantime he had become interested in plant physiology. In 1718 he was elected a fellow of the Royal Society, on the nomination of his old friend William Stukeley, and on March 15 of the same year he read before the society a paper entitled "The effect of ye sun's warmth in raising ye sap in trees." His "Vegetable Staticks," the classic which includes practically all his work on plant physiology, was published in 1727 under the Imprimatur of Sir Isaac Newton, who was serving his last year as president of the society. The importance of the volume was immediately recognized, and probably contributed largely to his election as a member of the council of the society the same year. "Vegetable Staticks" was translated into French by Buffon in 1735, into German by Christian Wolff in 1748, into Dutch in 1750 and into Italian in 1756. Both his "Vegetable Staticks" and "Haemostaticks" were gaining Stephen Hales international renown, and in 1733 they were combined in a single volume entitled "Statickal Essays." The same year he was awarded an honorary D.D. degree by Oxford.

Stephen Hales's work in plant physiology was along four principal lines: water relations, growth, nutrition and reproduction. By far the most extensive and valuable of those were his studies of water relations, *i.e.*, transpiration, conduction, root pressure and absorption.

He employed three methods of measuring transpiration: weighing, a potometer and a glass balloon for collecting the water transpired. The first two methods are still in use, and the latter has been discarded only in relatively recent years. He determined the rate of transpiration per unit of leaf area for sunflowers, cabbage, grapes, apple trees, lemon trees and a number of other plants with a surprising degree of accuracy. He discovered the daily periodicity of transpiration, and noted that "with scanty watering the perspiration much abated." He showed that evergreens transpire less

than some other plants. He first pointed out the correct explanation for the removal of some leaves after transplanting, a common custom even in those days.

His research on root pressure was suggested to him by his work on blood pressure and an accidental observation. Here are his own words from his "Vegetable Staticks":

> About twenty years since I made several haemostatical experiments on dogs; and six years after repeated the same on horses and other animals, in order to find the real force of the blood in the arteries: at which time I wished I could have made similar experiments to discover the force of sap in vegetables; but dispaired of ever effecting it, till about seven years since, by mere accident I hit upon it, while I was endeavoring by several ways to stop the bleeding of an old stem of a vine, which was cut too near the bleeding season, which I feared might kill it. Having, after other means proved ineffectual, tied a piece of bladder over the transverse cut of the stem, I found the force of the sap did greatly extend the bladder; when I concluded, that if a long glass tube were fixed there in the same manner, as I had done before to the arteries of living animals, I should thereby obtain the real force of the ascending sap in that stem, which succeeded according to my expectation: and hence it is that I have been insensibly led on to make farther and farther researches by variety of experiments. . . . March 30th at 3 p. m. I cut off a vine on a western aspect, within seven inches of the ground; the remaining stump had no branches: it was four or five years old, and ¾ inch diameter; I secured the joint with stiff cement made of melted bees-wax and turpentine, and bound it fast over with several folds of wet bladder and packthread: I then screwed a second tube to the first, and then a third to 25 feet height. The stem not bleeding into the tube, I filled the tube two feet high with water; the water was imbibed by the stem within 3 inches of the bottom, by 8 o'clock that evening. In the night it rained a small shower. The next morning at 6 and ½, the water was risen to three inches above what it was fallen to last night at eight o'clock. The thermometer which hung in my porch was 11 degrees above the freezing point. March 31 from 6 and ½ a. m. to 10 p. m. the sap rose 8 + ½ inches. April 1st, at 6 a. m., thermometer three degrees above the freezing point, and a white hoar frost, the sap rose from 10 o'clock last night 3 + ½ inches more; and so continued rising daily till it was above 21 feet high, and would very probably have risen higher, if the joint had not several times leaked: after stopping of which it would rise sometimes at the rate of an inch in three minutes, so as to rise ten feet or more in a day. In the chief bleeding season it would continue rising night and day; but much more in the day than night, and most of all in the greatest heat of the day.

In his next experiment he substituted a U tube mercury manometer for the glass tube and secured a pressure of 32.5 inches of mercury, or 43 feet of water. He conducted numerous experiments on root pressure, but the data he secured, important as they were, were probably exceeded in value by the techniques he introduced. The quaintness of his language in the above passage does not obscure his careful observations, his recording of all factors which might be of possible importance in interpreting his results, his constant use of quantitative measurements and his clear, concise descriptions—all innovations in the study of plants. Nor have his experimental techniques been greatly improved even to-day.

Hales summarizes his extensive experiments on water conduction as follows: "These last experiments all show, that although the capillary sap-vessels imbibe moisture plentifully; yet they have little power to protrude it farther, without the assistance of the perspiring leaves, which do greatly promote its progress." Here was a theory of sap rise which, despite its reliance on capillary action, came nearer to the modern cohesion of water theory than anything else ever proposed.

Of Hales's other work on water relations of plants perhaps the most important was his demonstration that there is no circulation of sap and that the path of water was upward through the wood. He gave the correct explanation of the cessation of bleeding after leaves form. He noted that water absorption decreases daily in cut branches, and that the former rate could be partially restored by cutting a fresh surface.

Hales devised methods of determining the distribution of growth similar to those employed to-day. He spaced pins in a row on a handle to measure growth distribution in stems, and in squares on a square of wood to measure leaf growth. By dipping the pins in red lead and oil he was able to mark the stems or leaves and follow their growth. His theory of growth was not so satisfactory. He believed that air and sap pressed on the shoot with sufficient force to cause growth, and tried to relate growth to the imbibitional forces he observed in swelling pea seeds.

He was the first to suggest that air is involved in plant nutrition, and might have discovered photosynthesis had chemistry not been so undeveloped, but he could not progress beyond the following vague concepts:

> Plants obtain nourishment not only from the earth but also more sublimed and exalted food from the air, that wonderful fluid, which is of such importance to the life of vegetables and animals. . . . For the air is full of acid and sulphurous particles which, constantly forming in the air, are doubtless very serviceable in promoting the work of vegetation; when being imbibed by the leaves, they may not improbably be the materials out of which the more subtle and refined principles of vegetables are formed. . . . We may therefore reasonably conclude that one great use of leaves is to perform in some measure the same office for the support of vegetable life, that the lungs of animals do for animal life; plants very probably drawing thro' their leaves some part of their nourishment from the air. . . . May not light, which makes its way into the outer surfaces of leaves and flowers, contribute much to the refining of substances within the plant?

Here speculation replaces the experimental evidence characteristic of his work on water relations, though it is interesting to note that he delayed the publication of "Vegetable Staticks" two years in order to conduct numerous experiments in which he subjected miscellaneous vegetable and animal substances to distillation, fermentation, acids, and so forth, collecting the gases produced over water. These experiments provided the basis for his statement that the substance of plants might be partly derived from the air.

Stephen Hales's other field of investigation in botany was reproduction, but here he contributed nothing of value. His theory was similar to Grew's and was briefly as follows: sulfur attracts air, farina (pollen) abounds in sulfur and so unites with the air inspired at several parts of the plant, especially the pistillum; it is then conveyed to the capsula seminalis where light is added, and thus the three most active principles in nature are combined to form a punctum saliens to invigorate the seminal plant. What a striking example this is of the results secured when conjecture replaces experimentation! Here Hales's work belongs to the botany of the fifteenth century; his work on water relations belongs to that of the twentieth.

Hales also made several contributions to gas chemistry and invented the pneumatic trough, which made possible modern advances in the field, although this is usually credited to Joseph Priestley. Indeed, some of his biographers rank his chemical work on a par with his physiological work, though this hardly seems justified. From the standpoint of the scientist, and especially the botanist, it is extremely unfortunate that at the height of his scientific fame he practically deserted his work in pure science for other interests. At this time he was only fifty-six years old and had twenty-nine years of life ahead of him.

He became a trustee of the Colony of Georgia, a position which he filled until near the end of his life. This public service required much of Hales's time and energy. That his efforts did not go entirely unappreciated is indicated by the fact that the naturalist governor of the Colony, John Ellis, named the genus *Halesia* (Silver Bell) in his honor.

His scientific interests had now turned

to applied science and invention. In 1739 he published a volume, entitled "Philosophical Experiments," describing numerous inventions and applications of science to human welfare. Between then and 1756 he published four other similar volumes. His work included such diverse subjects as methods of dissolving the calculus or kidney stone, ventilation, improved methods of distilling fresh from salt water, preservation of water and meat on sea voyages, methods of cleaning harbors, deep sea gauges, use of furze in fencing river banks, methods of preventing the spread of fires, thermometers for high temperatures, natural purging waters, preserving corn from weevils by fumigation with brimstone, salting meat by passing brine through the arteries of the uncut animal, earthquakes, keeping gun powder dry at the mills, and freeing mines from asphyxiating and explosive damps.

His work in applied science was inferior to his work in pure science, and few of his inventions were actually of practical value. His favorite invention was his ventilator and, together with his crusade against gin, held the major part of his attention during his declining years. He believed in ventilation for plants as well as humans, and when the Princess of Wales was having a greenhouse erected at her Kew Gardens she asked him to install a ventilator in it.

In 1739 he had received the Copley Medal of the Royal Society. Ironically enough, it was for his research on the calculus, according to Clark-Kennedy "the least successful and credible of all his scientific work." In 1753 he was elected one of the eight foreign members of the French Academy. In 1756 he conducted his last recorded experiment, returning once more to pure science. He studied the effect of blowing air through a bucket containing several fish, with a similar bucket of fish as a control. He also investigated the nature of gill breathing.

When Stephen Hales died in 1761 a memorial was erected to him in Westminster Abbey, but he had expressed the wish to be buried under the porch of his church at Teddington. His epitaph, long since worn away, has been reproduced on a brass plate erected on the nearby tower by a group of botanists in 1911.

That this was done by botanists was most appropriate, for despite Stephen Hales's varied activities and the fact that his active botanical researches extended over only about twenty years of his long career, his most lasting claim to fame rests on his work in botany. Only his work in animal physiology approaches in importance his contributions to botany. In animal physiology he was contributing to a science already well established by the work of Harvey and others; in botany he himself established plant physiology as a definite phase of science. With the possible exception of the isolated and rather meager work of Cusanus, Boehm, Van Helmont and a few others, he introduced an entirely new approach and new methods and techniques in the study of plants: the use of physical and chemical principles in the explanation of plant processes, the use of carefully conducted and controlled experiments as the source of information about plants, and the use of various measuring devices which put the new science on an accurate quantitative basis from the start. Nor was this all: he did his work so well that few of his results have been invalidated by modern research. His studies in water relations, to which he devoted most of his attention, provided much of our fundamental knowledge in this field and are occasionally referred to even in modern textbooks, not as curiosities, but as sources of information.

The historians of botany have almost universally accorded him praise, in striking contrast to the severe criticism many of them have directed against his

more widely publicized contemporary, Linnaeus. Several historians express the opinion that Linnaeus, through his widely accepted artificial system of taxonomy, retarded the development of a natural system of taxonomy as much as a century. No similar charges are directed against Hales. The nearest approach to an adverse criticism of Hales is the following passage by Green:

> Great as was the advance that Hales made from the standpoint of Grew, he did not attain anything like the modern position of physiologists. If we study his writings with greatest care we fail to find in them any recognition of a living constituent of the plant dominating its various mechanisms. The sap seems to be the all-important thing, and its movements, its refinement under the influence of light, and its various fermentations take the place that is now given to the living substance. Hence his explanations of physiological phenomena were purely mechanical. The vagueness of Grew is not entirely absent; we find him saying of light that "it contributes to the ennobling of vegetables." His knowledge of the functions of the various organs of the plant was naturally in many respects imperfect—we can only wonder that it was so extensive, for those were still the days of the infancy of chemistry as well as of physiology.[5]

Hales seems to have had a dualistic concept of plant processes: he believed that certain processes ("staticks") could be explained entirely by physical and chemical principles, while others (vital) could not be explained by science. Sachs points out that, "Permeated with the spirit of Newton's age, which notwithstanding its strictly teleological and even theological conception of nature did endeavor to explain all the phenomena of life mechanically by the attraction and repulsion of material particles, Hales was not content to give a clear idea of the phenomena of vegetation, but sought to trace them back to mechanico-physical laws as then understood."[6] Hales's freedom from teleological explanations is indeed remarkable, and he used terms with teleological implications only rarely. Sir Francis Darwin's comments in this connection are of interest:

> Whewell points out in his "History of the Inductive Sciences" that the physiologist asks questions of nature in a sense differing from that of the physicist. The *Why?* of the physicist meant *through what causes?* and that of the physiologist *to what end?* This distinction no longer holds good, and if it is to be applied to Hales it is a test which shows him to be a physicist. For, as Sachs shows, though Hales was necessarily a teleologist in the theological sense, he always asked for purely mechanical explanations.[7]

Another aspect of Hales's work which receives favorable criticism from the historians is his aptness at experimentation and the cleverness of his experimental techniques. Hales introduced into plant physiology the processes of weighing and measuring, leaving nothing to vague assertion or inaccurate estimation. Nordenskiöld comments: "In his ability to organize biological experiments and draw conclusions therefrom he was excelled by none of his contemporary scientists and by but few of those that have come after him; it has been possible even in modern times to apply his experimental methods with profitable results."[8] In a similar vein Darwin points out that, "His successors have discovered much that was hidden from him, but consciously or unconsciously they have all learned from him the true method and spirit of physiological work."[9]

That Hales fully appreciated the method and spirit of science is indicated by the following passage from the Preface to his "Haemastaticks":

> Though we can never hope to attain to the complete knowledge of the texture, or constituent frame and nature of bodies, yet may we reasonably expect by this method of experiments, to make farther advances abundantly

[5] J. R. Green, "A History of Botany," p. 203, London, 1914.

[6] "History of Botany," p. 477.

[7] Sir Francis Darwin in "Makers of British Botany," F. W. Oliver, ed., p. 67, Cambridge, 1913.

[8] Erik Nordenskiöld, "The History of Biology," p. 253, New York, 1932.

[9] "Makers of British Botany," p. 68.

sufficient to reward our pains. And though the method be tedious, yet our abilities can proceed no faster; for as the learned author of the "Procedure of Human Understanding" observes, "All the real true knowledge we have of nature is entirely experimental, insomuch that, how strange soever the assertion seems, we may lay this down as the first fundamental unerring rule in physics, That it is not within the compass of human understanding to assign a purely speculative reason for any one phenomenon in nature." So that in natural philosophy, we cannot depend on any mere speculations of the mind: we can only with the mathematicians, reason with any tolerable certainty from proper data, such as arise from the united testimony of many good and credible experiments. Yet it seems not unreasonable, on the other hand, though not far to indulge, yet to carry our reasonings a little farther than the plain evidence of experiments will warrant; for since at the utmost boundaries of those things we clearly know, there is a kind of twilight cast from what we know, on the adjoining borders of *terra incognita,* it seems therefore reasonable in some degree to indulge conjecture there: otherwise we should make but very slow advances in future discoveries, either by experiments or reasoning: for the new experiments and discoveries do usually owe their first rise only to lucky guesses and probably conjectures, and even disappointments in these conjectures do often lead to the thing sought for: thus by observing the errors and defects of a first experiment in any researches, we are sometimes carried to such fundamental experiments, as lead to a large series of many other useful experiments and important discoveries.

CHANGES IN LAND UTILIZATION IN SOUTH SEA ISLANDS

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THE South Sea islands came to the attention of the people of the Western world at a time when the religious faith of Europeans was being specially stirred by Christianity. One result of this was the sending of Christian missionaries to these far-flung specks of land on the opposite side of the globe. The pioneer ship *Duff* of the London Missionary Society first reached Tahiti in 1797. It was not many years until all the Polynesian peoples, and most of the Melanesians of the South Seas, had adopted the new religion.

With the adoption of Christianity the brown-skinned peoples also took on clothes. Various other transformations in their ways of living took place. Among the last things to change were their methods of land utilization. Western methods of farming now being adopted mark the complete breakdown of native island civilization and a new method of life ill suited to the cultural values of the indigenous people.

The land in South Sea islands is held in large areas, each owned by an extended kinship group governed by a chief. The chief is an executive and designates certain areas to be worked by the families in his clan or tribe. In Samoa the *aiga* is the kinship group, ruled by a *matai,* or head, who directs its economic and political activities. In Fiji the *mataquali,* or clan, is the land-owning group.

For planted crops like taro, the more important crop in many islands, a clearing is made in the forest by girdling the trees or burning the bases of the trunks. Trunks and large branches are left lying on the ground. Dry brush is gathered and burned. Taro tops are stuck in holes made with the digging stick of the native. Taro plants in the clearings grow in various stages of development from slips a few weeks old to mature plants seven or eight months old.[1] Yams are planted

[1] See J. W. Coulter, "Land Utilization in American Samoa," pp. 25–27, Bernice P. Bishop Museum, *Bull.* 170, 1941.

by gathering the earth about cuttings and piling the soil higher as the tuber develops.

When two or three crops are raised, the clearing is abandoned. Another area is similarly cleared and the agricultural process is repeated. In the warm, rainy climate, trees and shrubs soon grow up again in the abandoned plot. In ten to fifteen years the soil has become rejuvenated, and after that time the natives go back to the erstwhile planted area, clear it over again and plant a new crop. It is a process of rotating the land instead of the crops. The cultivated plots are widely scattered. This is a form of primitive economy in which the amount of land needed for a small group of people is large.

No regular method of planting tree-crops is followed by the indigenous people. On many lands where coconuts grow the trees are a volunteer growth, sprung from nuts which have fallen. Bananas are usually planted in parts of the coconut plantations near the villages. There is no systematic planting of breadfruit trees, which grow for many years—Samoans do not know exactly how many. Besides furnishing one of the staple foods, the tree is extensively used on some islands for building native houses. Among several other tree crops, pandanus and paper mulberry are important; but they occupy a small part of the area used.

Large areas on islands are natural forest or bush, characterized by an extraordinarily luxuriant growth of vegetation. Epiphytes grow in the branches of trees and shrubs, and vines form masses over their stouter associates. The forest affords useful products without requiring any replenishment. Some of them are important as emergency foods, gathered after destructive hurricanes. The forest is most important in that it supplies lumber for making boats and houses; fiber for girdles and cord; wood for digging sticks and tapa beaters. Various kinds of flowers are taken from the forest to perfume coconut oil.

These methods of land use worked well because of the small density of population in South Sea islands, and a large area of agricultural land. When the United States took over American Samoa in 1900, the total population was 5,679 in an area of some 60 square miles, that is about 95 persons per square mile. In the Fiji Islands in 1881 the native population was 114,748, and the total population 127,486. Those islands have a total area of 7,083 square miles.

In the early days there were certain checks on the increase in population which kept the numbers of people in the islands at about the same figures. Frequent tribal wars took their toll of native lives. There was a very high infant mortality rate because of unsanitary surroundings and ignorance of child hygiene and nutrition.

This method of land utilization fitted in with the culture and environment of the people. It was an indifferent and irregular kind of cultivation. In the native scheme of food production no one was called on to labor diligently and regularly. All were fed and sheltered with plenty of time left over for social gatherings, recreation and lying in the shade. No one lived below a comfortable subsistence level. There was scarcely any time when frugality and thrift were necessary.

Each day had its own schedule, which was not known until the morning or perhaps the evening before. Samoans still rise before daylight and do their hard work before the sun is high. After their labors, they return to the village and have a light meal; during the afternoon they rest, stretched on mats in their homes. The main meal of the day is eaten about sundown.

Methods of land utilization were not the best adjustment to the native's natu-

ral environment, but they were adequate. They involved no problem of note which was forced upon his attention. Every one was satisfied and there was no incentive to progress in the western sense of the word.

On many islands land is now owned in fee simple by individuals and registered under their names in the land office of the government. We can find blue prints with the boundaries marked exactly, just as in a land office in the United States.

Systems of land tenure are similar to those in Europe and America. We find land leased by one native to another. Land is inherited by a son from his father under the English system of primogeniture.

Natives carry on small farming, raising several crops, some of them "money crops." In the *malae*, or public square, in Pago Pago in American Samoa there is a market day once a week. In the Pago Pago Bay district the Samoans are supported in part by a commercial economy. There is a lively little trade in taro, bananas and other products from outlying villages. Native commerce has become part of a world economy.

Many Fijians have renounced their time-honored methods of agriculture and become peasant farmers. This has meant separation from their old cooperative communal ties, and psychological transformation into individualists. A Fijian wishing to become a peasant farmer can secure an official exemption from the communal duties which fell to his lot as a member of a native village community. The government arranges for the successful applicant to have a lease on ten acres of land for ten years. Fijians raise sugar cane, bananas and rice and sell them. In some parts of the islands one sees them plowing with horses.

I was a guest of the Fiji Department of Agriculture to the Central part of the island of Viti Levu where, in the Waindina basin, members of hill tribes of Fijians have been established on small farms to raise bananas. They like this crop, for it requires little work. They are on government land which was leased to them rent-free for the first two years, and after that for a small sum. They raise a variety of Cavendish banana which takes about ten months to mature. Agricultural officers and assistants visit the district regularly, inspect the plantings, supervise the harvesting and packing of the fruit, market it and pay the natives. The fruit is transported by river to Suva on bamboo rafts which the natives call "no come back" boats. At Suva the rafts are broken up and sold and the boatmen walk home.

Various other crops are raised by Fijians who attempt to raise produce for a market. Market gardening is carried on by natives living near Suva. They raise vegetables for the local English market: cabbages, cauliflowers, lettuce and tomatoes. The mobilization of troops in Suva and the presence of soldiers from New Zealand have enlarged the market. Natives on the island of Kandavu raise similar vegetables and ship them in their small boats to Suva. There are native growers of citrus fruits, papaias and avocadoes.

There are several reasons for the changes from the ancient traditional ways of land tenure and land use to modern, Western methods.

The population of various islands has multiplied and has increased the pressure on the land for means of subsistence. The population of American Samoa is now 12,908 compared with 5,679 when the United States accepted the cession of the islands. The increase in population is due in part to the fact that a Western government established an era of peace in the islands. A much more important factor in the increase is the establishment of a régime of medical service and sanitation, the extent of which, in view of the small number of

the total population, is scarcely to be found elsewhere among a native people. A Department of Public Health was established in American Samoa in 1914. Medical service in the group of islands is entirely free. The thing which Samoans need most is being supplied by the government. The change in native economy itself has also been a factor in the increase of population.

The population of Fiji is now 220,787, nearly twice as much as it was in 1881. This has meant more intensive use of the land.

However, an important reason for the change in Fiji was the immigration of East Indians as indentured laborers on sugar-cane plantations and later their establishment as peasant farmers.[2] The time-expired Indian immigrant rarely sought reengagement as a plantation laborer. On the completion of his term of indenture he had little difficulty in leasing from native or from European owners sufficient land for his requirements; and was able by the cultivation of rice, corn or other crops for which there was a small market to ensure a sufficient and not too arduous means of livelihood for himself and his family.

In 1921 and subsequent years the Colonial Sugar Refining Company of Fiji established its plantation laborers on its lands as lessees, the company paying its tenants for the amount and quality of the sugar cane produced.

The regular work of Indian farmers in Fiji is in contrast to the irregular, easy-going life of the Fijians. The oriental rises at half past five in the morning and works at intervals until sundown; resting for awhile, however, during the hottest time of the day.

During the past two decades the government of Fiji has noted with concern the rapid increase in the population of Indians and the development of the agricultural resources of the islands by their methods of peasant farming. Indians have secured more and more land on leases from the Fijians, and many have employed natives to work for them.

The present director of agriculture, shortly after assuming the duties of his office, realized that little progress had been made in the development of modern agricultural methods by the Fijians, and that the formulation of some kind of policy by the government was essential to help the Fijians hold their own, economically speaking, in the islands. He has been the first to introduce and carry out a well-defined agricultural policy for the natives. The objective of the policy is the establishment of the natives as peasant farmers something like the Indians. But the problem is how to achieve this on behalf of a race which still preserves a strongly communal organization.

Another reason for the change in methods of land use is contact with western people. Europeans in the islands hold land in fee simple and farm it according to their own methods. This is the case in British Samoa and in Fiji.

In American Samoa I observed that a chief on an outlying island was insisting that plots of land be worked by families rather than communally. Although no land on his island was owned by any one in fee simple, it seemed that he was anticipating what was going to occur in the future.

American Samoans have been brought into close contact with our culture on the island of Tutuila. There are some 45 miles of secondary roads on that island, and the amount of travel on them helps to disseminate the westernized ideas of natives about Pago Pago Bay, who, for many years, have been closely associated with our Navy. Busses run between villages and the Naval Station. Many come in from outlying districts in the islands on steamer days to sell their wares to tourists.

[2] See J. W. Coulter, *Proc. 6th Pac. Sci. Congress*, Vol. IV, pp. 29–37, 1939.

The necessity for money is a reason for commercial agriculture. South Sea natives must purchase the minimum of clothes that they wear. Cotton takes the place of the old-time bark cloth, or tapa, which is now used only on ceremonial occasions. Men wear kilts (*lavalava* in Samoa) folded about the waist, and a good many wear shirts also. Women wear kilts and blouses. Shoes are not worn. Almost every village in Fiji has at least one hut with a galvanized iron roof. The iron must, of course, be purchased, and nails also.

The lack of markets for "money crops" has deprived many of them of the small incomes necessary to buy the few things for which they must have funds. The very low prices offered for copra—for so long a dependable cash crop of South Sea Islands—has been very discouraging. Their houses remain unlighted in the evenings, for they have no money to purchase kerosene for their lamps. When I visited a village on Viti Levu Bay, the only thing the people wanted in exchange for bananas was lamp oil. Some Fijians have gone back to the use of an improvised wick in coconut oil, expressing it themselves in a crude way from their unsold copra. Some make more native bark cloth from mulberry, for they can't buy cotton.

The increased population in South Sea Islands makes it necessary to use the clearings more often, and there is no longer opportunity for the soil or the forest to recuperate. In the mountainous country of American Samoa and Fiji a serious result of the repeated use of forest clearings for agriculture is soil erosion.

Under the new system of agriculture, soil conservation is a necessity which did not arise on account of their old methods. Forest and brush soon grew again in the clearings and held the soil in place, so soil conservation never became a problem. It is, therefore, difficult for a farmer to realize that if his land is continually cropped, methods of retaining the soil and rejuvenating it must be practised. Decreasing yields are a serious concern. He has never known the use of fertilizer, and crop rotation is an idea which has no meaning for him. The rapid washing away of soil even on gentle slopes is especially discouraging. The effect of the running water is much increased by an accepted practice of native farmers of making their rows up and down slopes instead of sideways along the contours.

The change to individual farming does not fit in with the philosophy of South Sea natives. The idea of being alone, independent and non-cooperative generally in his dealings with fellow men is not part of the social psychology of the indigenous people of the South Seas. And so many farmers yearn for the old life in a village community. They forsake their individual holdings and drift back again to be among their relatives and former friends. In 1930 the Colonial Sugar Refining Company at Labasa in Fiji placed twelve young Fijians on ready-made sugar-cane farms. As the years passed they became discouraged with the new type of life. One by one they drifted back to their villages, and when I visited the district in 1941 only one of them still remained on his farm. The company has had similar experiences in other districts.

It is significant that in the Census of 1936 there are no Fijians listed as storekeepers or traders. Trading by the natives has never been successful; a few attempts at forming merchandising companies have resulted in complete failure. The native storekeeper can not resist demands for credit, and soon his relatives, friends and neighbors have borrowed all his stock and he is obliged to go out of business. The urge to carry on the old communal generosity can not be reconciled with individualistic efforts.

The result of individualistic ventures is that the old Fijian social system is rapidly breaking down. The Fijian communal system for many years weathered the impact of our type of civilization; but it seems destined not to survive much longer, at least without considerable modifications.

The problem faced by South Sea Island governments is the stabilization of native character during the transition from communal life to whatever system replaces it. Dwarfed and condemned by individualism, the communal social system has begun to crumble and disintegrate, especially where the impact of the more self-assertive culture is strongest. This in the face of well-intentioned, if at times half-hearted, efforts to protect and conserve what is best for the good of the untutored majority as yet unfitted for any radical change in their society.

The attitudes of governments towards natives of South Sea Islands under their influence has remained essentially an economic one. To make the best commercial use of land is uppermost in the minds of American and British farmers, and this is reflected in the attitudes of their governments towards agricultural production. However, there is no evidence that the economic system of western civilization can be imposed on a native people with advantage to them.

Attributes of character of the natives of South Sea Islands which make it very difficult to adjust themselves to western culture can be traced to the environment in which their type of society has developed. A native's "knowing" things must be defined as a manner of reacting to his environment; his world is an isolated island where nature has been kind.

I close by saying: "Let me beg that we take an objective attitude toward ourselves, and look with humility upon the beliefs and attitudes which we cherish with such vehemence. Having achieved this end, we can react with sympathy and understanding towards the minds of others whose differing racial background, national history, social status or economic security give them an equally different outlook on life."[3]

[3] A. T. Poffenberger, SCIENTIFIC MONTHLY, July, 1933.

THE BOUNDARY OF LIFE

WE have known since Pasteur that there are two ways of poisoning the body—with a deadly chemical poison like arsenic or cyanide, and with a living infection like the bacillus of typhoid or tetanus. The difference between them is that the chemical poison has a direct effect only. Its action is proportionate to the original amount of the dangerous substance that touches or gets into our bodies. The living infection, on the other hand, may attack us as a single particle, but once it gets inside the body it can multiply without limit until it kills us and perhaps spreads to our neighbors and kills them.

There is no difficulty about this distinction, but in the last forty years a new borderline class of agents has gradually been recognized: the viruses. They are chemical compounds which are capable of crystallization, as Stanley found in 1935. But nevertheless they multiply within the body and can spread like any other plague. Are they living or non-living? It is useless to ask, for they themselves prove that the boundary between the living and the non-living is an artificial one. Now these viruses cause measles in man and foot-and-mouth diseases in cattle, and a hundred other dangerous but curable diseases of men and animals. But when they attack plants the disease is always incurable. They attack most cultivated plants, particularly those of the group to which the American crops tobacco, tomato and potato belong. And they are transmitted in a great many different ways—in every way except the obvious one of the seed. The gardener who is raising tomatoes has to take care not to smoke when he is tending his plants, or he may infect the tomatoes with a tobacco virus.—*"Monthly Science News," March, 1942, Canada.*

CONTINENTAL GLACIATION HYPOTHESES BEFORE LOUIS AGASSIZ

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AMERICAN geologists have accorded Louis Agassiz outstanding recognition for his interpretation of the significance of glacial phenomena, but physical evidences of glaciation puzzled the natural scientists long before his arrival in the United States. Without detracting from the accomplishment of Agassiz, it should be noted that his glaciation theories had been postulated to a considerable extent by foremost American scientists of the early nineteenth century. His contribution climaxed a discussion which had intrigued academic circles for some time before 1846, the date of his arrival. By tracing the history of this discussion through a half century, it is possible to note changes in scientific thought, especially in the field of geology.

Field observations of glacial debris in the northeastern states date from the last decade of the eighteenth century, when, in 1793, Benjamin DeWitt, a New York physician, published an account of erratics strewn along Lake Ontario shores. He attempted to account for their occurrence and distribution.[1] DeWitt and many who followed him were convinced that the position of such boulders was due to transportation by action of currents of water flowing over the surface of the land. This hypothesis, later known as the diluvial theory, proposed two explanations for the cause of the streams.

The first, and most logical idea, in view of the trend of scientific opinion, was that the deluge as described in Biblical accounts was a sufficient transporting power. A second hypothesis, simply conceived, accounted for streams or ocean currents overflowing the continent because of complete submergence of the land mass, but such a proposal involved the difficult problem of explaining such extensive submergence. Variations of these two themes called for shallow rivers flowing over the continent or greater development of ocean currents on a submerged land mass. Absurd suggestions included destruction of a huge barrier around the Great Lakes, releasing flood waters over large areas. Another scheme involved tectonic disturbances in the Arctic in order to explain changes of temperature with consequent melting of large ice masses. In all these theories the authors were careful to conform to the story of the deluge. Obviously some of these hypotheses were based in part on flights of fancy, rather than on factual observations.

H. H. Hayden, a Baltimore dentist who was interested in geology, published his "Geological Essays"[2] in 1820; this was the first serious consideration of glacial theory in scientific circles of the United States. Hayden's imagination supplied floating ice as an agent for transporting erratics. To him goes the honor for the first suggestion of ice action, though he did not realize the full import of his idea. Benjamin Silliman, professor of chemistry and natural history at Yale, in a notice of Hayden's book,[3] supported the author's views but expressed regret for the fanciful explanations of natural phenomena.

The most important exponent of the diluvial theory was Henry Darwin Rogers, professor of geology and mineralogy

[1] George P. Merrill, "The First One Hundred Years of American Geology," p. 615, 1924.

[2] Baltimore, 1820.

[3] *American Journal of Science and Arts*, 3: 47–57, 1821.

at the University of Pennsylvania, who directed the geological survey of New Jersey and Pennsylvania in 1836. On numerous occasions he expressed his opinion on the subject of the deluge. In his discussion of the origin of Niagara Falls, he ridiculed the idea of a seven-mile recession of the cataract by means of normal erosion processes.

> The whole of this region has been grooved and scarified by the same far-sweeping currents which denuded the entire surface of North America, and strewed its plains and mountains with boulders, gravel, and soil from the North. Such a diluvial valley, of greater or less depth was, I cannot help believing, probably the commencement of the present remarkable trough below the Falls.[4]

On numerous subsequent occasions he affirmed his belief in the validity of the diluvial theory, long after most American geologists were converted to Agassiz' theory of glaciation.

Edward Hitchcock, as state geologist of Massachusetts, subscribed to the tenets of the diluvial hypothesis. Other supporters included C. T. Jackson, state geologist of Maine and Rhode Island, and Charles Whittlesey, of Cleveland, who attributed the glacial terraces along Lake Erie to deposition by ocean currents.[5] George E. Hayes wrote, in 1839, "Can proof be more conclusive that these marks and scratches were produced by gravel, stones and boulders, swept over the surface of the rocks by currents, tides, or waves, which flowed from the north?"[6] William C. Redfield, astronomer, and first president of the American Association for the Advancement of Science, believed the presence of striae and positions of erratics were due to scarification and transportation by ocean currents and that their formation and deposition occurred during submergence, as their courses agreed with those of the ocean currents.[7] William Barton Rogers, brother of Henry D. Rogers, who served as professor of physics and chemistry at William and Mary College and the University of Virginia and who was placed in charge of the geological survey of Virginia in 1835, also supported the diluvial theory.[8]

Some of the most outstanding geologists in the country were convinced of the truth of the diluvial theory, and declined to agree with the views of Agassiz. Furthermore, the suggestion had already been made, a quarter-century before his arrival, that ice *and* water were responsible for the distribution of glacial debris throughout the northern states.

The diluvial hypothesis, despite its general acceptance, failed to satisfy some of the observed phenomena. Its enthusiasts offered no satisfactory explanation of polished rock surfaces or striations, and there were other serious inconsistencies between hypothetical and observational data. Chester Dewey, later professor of chemistry and natural philosophy at the University of Rochester, challenged the theory seven years before the arrival of Agassiz: "The friction of the water and earth in the Genesee wears somewhat smooth surfaces on the same rock, but nothing like the polished surface [noted in the field]. What is the power or cause which could have moved any hard body so as to have produced this result?"[9]

Ebenezer Emmons, geologist-in-chief of the second district of the Geological Survey of the State of New York, questioned the efficacy of water as an agent capable of moving quantities of soil and rocks from their original positions. In a report on two ore beds in the region south of Lake Champlain, he considered the possibility that their positions had been shifted southward by some unknown force.[10] The nature of such a

[4] *Ibid.*, 27: 326–335, 1835.

[5] *Ibid.*, 60: 31–39 (second series, vol. 10, 1850).

[6] *Ibid.*, 35: 191, 1839.

[7] *Ibid.*, 47: 120–121, 1844.

[8] *Ibid.*, 43: 180–181, 1842.

[9] *Ibid.*, "On the Polished Limestone of Rochester," 37: 242, 1839.

[10] New York Geological Survey, Fourth Annual Report of the Second Geological District, 1840, p. 313.

transporting agent was left in doubt, and Emmons was satisfied with a mechanical-religious explanation as if hesitant to express his true ideas on the matter. In support of the challenge to the theory he noted an apparent inconsistency between the time when striations occurred and the nature and extent of alluvial deposits overlying them.

In 1844, Edward Hitchcock joined the ranks of the dissenters, and expressed his conviction that the diluvial theory was inadequate, basing his conclusions largely upon the inability of water to produce the polished limestones which he had observed near Rochester.[11]

It may be noted that the changed point of view, and the trend of scientific opinion away from the diluvial theory were coincidental with beginnings of field observations for the state geological surveys. Those who made studies of the drift gradually came to see the need of an adequate causal explanation for the presence of glacial features in the landscape.

As the diluvial theory was found wanting, the second important concept was proposed to account for drift phenomena. It originated in 1837 or earlier with Peter Dobson, of Vernon, Connecticut, and became known as the iceberg hypothesis.[12] He suggested that large masses of ice from Arctic regions had floated southward, carrying rocks and gravel which were transported over the submerged continent and dropped in their present positions when the icebergs melted. The catastrophic origin of such bergs was doubted, but critics of the theory admitted that combined action of *ice and water* provided an explanation for observed glacial drift, striae, potholes and moraines. The whole question of the action and movement of icebergs was opened for discussion as the result of Dobson's thesis. Lengthy papers were written and much research on problems of glacial behavior took place.

John Lord Hayes, later chief clerk at the U. S. Patent Office, advocated the efficacy of icebergs and glaciers in transportation of material in an important paper presented before the American Association of Geologists and Naturalists.[13] The action of ice was stressed also by W. W. Mather, superintendent of the Ohio Geological Survey. He became the principal proponent of the iceberg theory, for it permitted him to account for field observations. He declared against the ideas of Agassiz, finding the concept of extensive glacial action in non-mountainous regions untenable.[14]

If proponents of the diluvial theory had trouble defending their views, J. L. Hayes and W. W. Mather had to meet more serious objections to their iceberg theory. Emmons gave three reasons for its rejection: it failed to explain polished rock surfaces; it did not account for uniform direction of striae; it failed to provide for the great age of the striae. His attempt to reconcile fact and theory appears in his statement:

> Is there any connection between the pot holes and the abrasions of the sandstone? We know the former could not have been produced by an iceberg, and probably not by the deluge, but we know they are the effects of running water. There may be a connection but it is not possible to demonstrate it. Both phenomena have the appearance of having been produced by one agent, but we are wanting in fact. . . .[15]

Hitchcock objected to the iceberg theory, chiefly because of the lack of explanation of low temperatures to produce glaciers and bergs.[16] In its place, he proposed the glacio-aqueous or aqueo-

[11] Association of American Geologists Report, 1844, pp. 45–49; 164–221.

[12] *American Journal of Science and Arts*, 46: 169–172, 1844, and Merrill, *op. cit.*, 619.

[13] *American Journal of Science and Arts*, 45: 316–319, 1843.

[14] "Geology of New York," First District, part 4, pp. 158–228.

[15] *Loc. cit.*, 313.

[16] First Anniversary Address before the Association of American Geologists, *Am. Jour. of Science and Arts*, 41: 256, 1841.

glacial theory, named to accord with the principal agent of deposition, ice or water. This hypothesis involved the use of ocean currents and icebergs, with an undetermined amount of glacial action, depending on the viewpoint of the individual. The combination of diluvial and iceberg theories effected a more ready acceptance of Agassiz' glacial theory. The combined theories were embraced by the more conservative American geologists, who admitted the force of Agassiz' arguments, but were reluctant to recognize the similarity of American and European drift phenomena. Hitchcock led the way, and in his anniversary address before the second annual meeting of the Association of American Geologists, he announced, "Henceforth glacial action must form an important chapter in geology." He recognized the validity of a glacial origin for all details of the landscape which had been unsatisfactorily explained by preceding theories, and he accepted Agassiz' ideas so completely that he was widely misquoted as an active supporter of the glacial theory in spite of the following statement: "To account for all the phenomena in this country, we want currents of water to flow over a large part of the surface, loaded with ice and detritus, for centuries at least."[17] At the following meeting of the association, he led a discussion on drift phenomena, and there acknowledged his indebtedness to Louis Agassiz, although he was convinced that an unmodified glacial hypothesis was not acceptable in America and failed to meet American conditions.

Within a short time, other geologists grew enthusiastic over the glacio-aqueous theory of Hitchcock. Chester Dewey, a supporter of the diluvial theory in 1839, stated four years later that in his opinion the position and appearance of glacial erratics in western New York seemed to require a combination of large masses of ice and a strong flow of water from the west of north to provide for their transport.[18] By 1844, Emmons was converted to the glacio-aqueous theory as the result of his careful studies of the Lake Champlain area. William Redfield, W. W. Mather and others soon stated their preference for this hypothesis, and thus made easy the acceptance of Agassiz' proposals.

Attempts to survey conditions in the field and increasingly acute interest in field surveys are apparent in a series of questions devised by geologists working under Mather's direction in the New York survey. Among others, these pertinent queries appear:[19]

> Where ledges of rocks have been recently uncovered by excavations, are the surfaces smooth, as if by the action of running water, or with pot holes, such as are seen at many water falls?
>
> Do any of these surfaces show grooves and scratches as if hard masses had been dragged over them?
>
> Are any large rounded or irregular masses of rock found in your neighborhood?
>
> Are there scratches on them in one or more directions?
>
> Are the rocks similar to ledges of rock known to you?

These leading and significant questions indicate a tendency toward field observation as a basis for geologic hypotheses, and the beginning of field techniques.

The glacio-aqueous theory was not intensely opposed by any American scientist except H. D. Rogers. Its supporters could provide no satisfactory reason for the postulated low temperatures and submerged continent. It did, however, clear the road for the acceptance of the work of Agassiz.

The glacial theory need not be repeated here. Its conditions were so log-

[17] Association of American Geologists Report, 1843, p. 217.

[18] "Striae and Furrows of the Polished Rocks of Western New York," *Am. Jour. of Science and Arts*, 44: 146–150, 1843.

[19] "Queries Proposed by the Geologists of the New Survey of the State of New York," *ibid.*, 33: 124, 1838.

ical that they were quickly recognized as valid, since they accounted for drift phenomena which had been observed in field studies in this country. It went a step beyond the glacio-aqueous theory, for it eliminated the need for submergence of the continental mass. One important challenge was left unanswered by Agassiz: the reason for temperatures so abnormally low that continental ice sheets began their southward advance. That challenge has not been answered yet, after a century of research.

American recognition of Agassiz' theory began as early as 1839, when Timothy Conrad, one of the assistants in the preparation of the New York Geological Survey from 1838 to 1841, declared in favor of continental glaciation, and wrote in its defense,

> M. Agassiz attributes the polished surfaces of the rocks of Switzerland to the agency of ice, and the "diluvial scratches," as they have been termed, to sand and pebbles which moving bodies of ice carried in their resistless course. In the same manner I would account for the polished surfaces of the rocks in western New York.[20]

Conrad's conclusions were based upon his studies of paleontology as well as field work on the drift phenomena. His views and those of Agassiz were similar to the opinions of Lardner Vanuxem, geologist in charge of the third district of the New York Geological Survey. The published papers of these men had comparatively little effect, for it was not until the significant address of Edward Hitchcock in 1841, as previously noted, that public and scientific interest was genuinely aroused in the glacial theory.

Outspoken opponents of the work of Agassiz included C. T. Jackson, who derided the glacial theory as both fanciful and imaginary.[21] He wrote, "This country exhibits no proofs of the glacial theory as taught by Agassiz, but on the contrary the general bearing of the facts is against that theory. . . ."[22] Jackson was seconded by Jean Nicholas Nicollet, who had come to North America in 1832 to study physical geology and geography. His point of view was even more positive than that of Jackson, for he found it "impossible to conceive how the effects described by M. Agassiz to the moving glaciers could with propriety belong to them."[23] Chester Dewey,[24] Henry D. Rogers[25] and W. B. Rogers[26] also challenged the glacial theory, but the most serious objections were expressed by Edward Hitchcock. He required satisfactory evidence of low temperatures and the presence of ice sheets. He was unable to accept the idea of ice in motion without transportation by water, or that ice would be able to carry erratics from valley floors to higher levels.[27] Such questions had to be answered to the satisfaction of the American geologists before the theory of continental glaciation could be applied to conditions in this country. By 1850, Agassiz had been able to convince all the most conservative scientists of the validity of his hypothesis, and many of his former opponents went to his support.

The change in glacial theory that occurred within the half century from 1800 to 1850 began with completely catastrophic explanations of drift phenomena, progressed through a maze of partly acceptable theses, and emerged finally as the comparatively satisfactory proposal of Louis Agassiz. His views have endured, but more significant than changes in glacial theory were changes in research methods, with final emphasis placed upon the need for adequate field studies and hypotheses which met the conditions found in the field.

[20] "Notes on American Geology," *ibid.*, 35: 237–251, 1839.
[21] *Ibid.*, 45: 320–323, 1843.
[22] *Ibid.*, 43: 151, 1842.
[23] *Ibid.*, 45: 323, 1843.
[24] *Ibid.*, 44: 146–150, 1843.
[25] *Ibid.*, 43: 180–181, 1842.
[26] *Ibid.*
[27] *Ibid.*, 43: 396–398, 1842.

CHINESE CHEMICAL TERMS

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MELLOR has spoken of the close relationship of the nomenclature of a science to the science itself and quotes Lavoisier to say that "like three impressions of the same seal, the word ought to produce the idea and the idea ought to be a picture of the fact."[1] This close relationship, because of the ideographic nature of the language, is produced in the Chinese chemical nomenclature.

As against the twenty-six letters of the Latin alphabet, available to the American chemists for use in writing names for various chemical elements and compounds, the Chinese chemist has a much wider choice. There are thirty to forty thousand distinct written characters found in the standard dictionaries, of which, however, only four to five thousand are in common modern use as exemplified in the vocabulary of the present-day newspapers. Hence there is a wide choice available for the character whose meaning and method of writing will be most suitable as the name of the chemical substance in question.

During the fifty odd years of modern Chinese chemistry, there have been three tendencies in regard to chemical terminology. The first has been to continue the use of the English terms. Since all students studied English in the high school this plan offered little difficulty. However, as the curriculum steadily increased the amount of science teaching, difficulties were met with and there arose a demand for the teaching to use entirely Chinese terms.

Another tendency, especially in the early years of this century, was to borrow the Japanese chemical nomenclature. This had been well worked out, and many text-books were being translated from Japanese into Chinese. Moreover, the ease of learning Japanese, the written language of which uses many Chinese characters, and the large number of graduate students who went to Japan to study also influenced this tendency. But the rising tide of feeling against Japan's aggression has made such a plan unthinkable to patriotic Chinese.

The third tendency has been to study the various systems of nomenclature and carefully prepare a standardized list of Chinese terms. A committee was appointed by the National Government Bureau of Education, and in 1933 there was published a list of such terms and the methods to be followed in naming inorganic and organic substances.[2] The principles followed in the creation of this standard chemical terminology have been discussed by Adolph.[3] This standard terminology has been universally adopted throughout China.

Before discussing these terms it is necessary to say a word about the construction of written Chinese. The author's first introduction to Chinese characters was to that type which is called "grass" writing. It is very easy to look at this form and wonder how any one can make sense out of it (Fig. 1a). The simplicity and order which underlie Chinese writing, its precision and beauty are not apparent to the casual observer in this kind of writing. Similarly, the beauty inherent in written English as revealed by the printing of a gifted drafts-

[1] J. W. Mellor, "Modern Inorganic Chemistry," p. 51, 1925.

[2] Hwa Hsuch Ming Ming Yuan Tse; Chinese National Publishing Bureau, 1933.

[3] W. H. Adolph, *Jour. Chem. Ed.*, 4: 1233, 1927.

FIG. 1. "NORMAL PHOSPHATE" CHARACTERS WRITTEN TO SHOW THE DIFFERENCES BETWEEN THE "GRASS STYLE" (a) AND THE "KAI STYLE" (b) OF WRITING.

man is not observed in the typical scrawl of most chemists. To see the Chinese character in its essential dignity look at the writing in the "kai" style (Fig. 1b). Here the formal is emphasized. It is this form which is used as the standard for schoolboys. Patient copying of the characters as written by the old masters is the most fruitful method to teach the artist-calligraphist a good style. This ability has always been rare and is becoming more so, for the use of the lowly fountain pen in the schools is displacing the Chinese brush-pen which is necessary for beautiful writing.

In the examination of the "kai" style the division of all characters into a "radical" and a "phonetic" is usually quite easily observed. The total number of radicals is two hundred and fourteen. Phonetics number about eight hundred and ninety,[4] and often give a direct clue to the sound of the character. Hence the terrifying complexity of the vast numbers of quite distinct characters is reduced by the analysis of their structure into the radical and phonetic, the total number of types of which is slightly over eleven hundred (Fig. 2).

The Chinese language is monosyllabic, that is, each character has its distinct sound of one syllable. Characters and their syllables are put together and built up to convey a precise meaning. Yet these built-up expressions are extremely short. Compare the length of the English term "the freezing-point depression," with the French "l'abaissement du point de congélation," the German "Gefrierpunktserniederung" and the short four-syllable Chinese expression, "ping tien chiang ti."

Chinese grammar is extremely simple and adaptable. There is a freedom that is astonishing to any one who has suffered from English grammar. Declensions of nouns, verb endings, verb tenses are all absent. Many verbs can be used without change as nouns. Singulars and plurals are oftentimes conveyed by inference or the sense of the connection. This gives great freedom in constructing new terms to express scientific concepts and ideas.

[4] W. E. Soothill, General Pocket Dictionary; Presbyterian Mission Press, Shanghai, 1928.

Modern Chinese seems to have greater adaptability than modern English. Certain scientific ideas are with difficulty expressed in English and require special terms based upon Greek or Latin words. The same ideas readily find expression in modern Chinese. It is a common experience of Westerners teaching in China to prepare examination questions which when translated into Chinese are a dead give-away. One examination question read, "to tell the difference between the structure of isotopes and isobars." But isotopes are translated as "similar number elements" and isobars "similar weight elements." The original question had lost much of its examination value. Such Chinese terms state the idea involved more clearly than do the English terms.

The above features of the Chinese language are shown in the discussion of a few scientific terms below.

1. *Science.* This is translated by a two-character term, "k'o hsueh." The first means a class, a series or rank; the second is to learn or to study. Hence the literal meaning of the translation is, *the study of classification.*

2. *Chemistry.* Another two-character expression, "hwa hsueh." Two verbs, the first, to change or to transform, the second to learn or to study, being combined to make a noun and meaning *the study of change or transformation.*

3. *Analysis.* "fen hsi," again two verbs combined, both with the idea of dividing, of splitting. This term may be used as either verb, noun or adjective.

4. *Qualitative.* "ting hsing," the first being to fix, settle, decide and the second is disposition, qualities or nature. Hence the *determination of qualities.*

5. *Isomorphous.* "tung hsing ti," the first character means identical, the second, form, figure or shape, while the third is body. So the combined meaning, *bodies of identical shape or form.*

In chemical nomenclature a simple method is used to differentiate between those elements which are gaseous, liquid or solid. The radical called "chi" denoting gaseous properties, is combined with suitable phonetics to represent any one of the gaseous elements (Fig. 3). Similarly, the radical "shui," for water, is used for the liquid elements (Fig. 4). The non-metallic solid elements make use of the radical "shih," meaning a stone, while the metallic elements use the radical "chin" indicating gold (Figs. 5, 6). In this way the Chinese written term for an element includes more information than does the English term as it reveals the physical state.

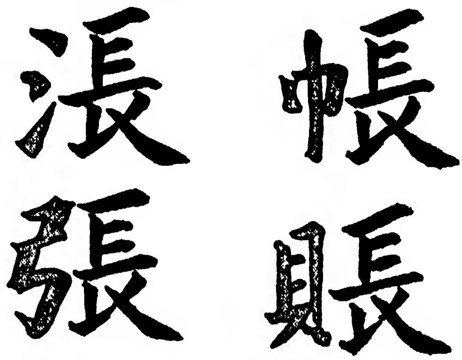

FIG. 2. CHINESE CHARACTERS WRITTEN TO ILLUSTRATE THE COMMON PHONETICS COMBINED WITH DIFFERENT RADICALS.

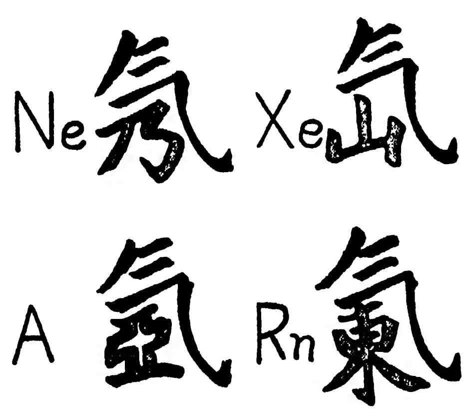

FIG. 3. INERT GAS CHARACTERS ILLUSTRATING THE COMMON "GAS" RADICAL, WHICH IS WRITTEN IN SOLID BLACK.

Wherever possible the sound of the Chinese character used approximates the sound of the chemical symbol. Masurium has the symbol "Ma," while the sound of the Chinese character is also "ma." Similarly, the sound for the lithium character is "li," for bismuth, "pi." To do this, it has been necessary in some cases to use very rare characters or even entirely new combinations of phonetics with the suitable radicals.

To illustrate the nomenclature for inorganic compounds, a few examples have been selected and are presented as follows.

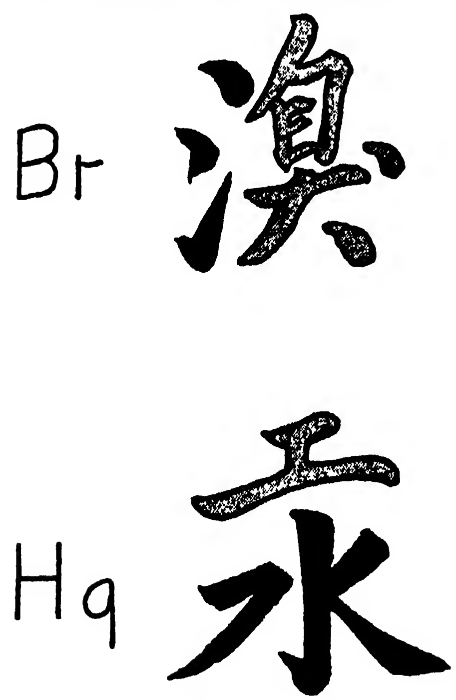

FIG. 4. LIQUID ELEMENT
CHARACTERS WITH THE "WATER" RADICAL WRITTEN IN SOLID BLACK IN ITS TWO FORMS.

1. *Oxides.* A three-character expression has been adopted which literally translated reads, "oxygen change X" where X represents the other element. For silver oxide, we would say "oxygen change silver." The term joining the oxygen and silver is "hwa" which is part of the name of chemistry, as above explained.

2. *Binary Compounds.* Similar in form to that used for oxides. If the positive valence element has two valencies, the "ic" form is named as per the oxides. The "ous" form, as with ferrous chloride, is called "chlorine change inferior iron." However, another set of terms following the molecular formula as "three chlorine change iron" and "two chlorine change iron" are also in use. Both methods are combined in naming the numerous oxides of nitrogen or manganese.

3. *Binary Compounds of Hydrogen.* These are named as per other binary compounds, but if the aqueous solution is an acid, the translation is "hydrogen X acid" as for hydrochloric acid, "hydrogen chlorine acid."

4. *Radicals.* A distinction is made between a radical as such and when it carries an electric charge. The former is a "chi," while the latter condition is a "ken." This is made clear by the following illustration.

NH_3	"an" (special short name for ammonia, character is written with the gas radical)
$-NH_2$	"an chi"
$=NH$	"inferior an chi"
NH_4^+	"an ken" (character here for "an" has the metallic radical)

5. *Oxygen Containing Acids.* The order of naming follows closely the English terminology. Sulfuric acid is "sulfur acid" while sulfates as lead sulfate are written "sulfur acid lead." For a series of acids various prefixes are used, as below.

HCl	hydrogen chlorine acid
$HClO$	secondary chlorine acid
$HClO_2$	inferior chlorine acid
$HClO_3$	chlorine acid
$HClO_4$	exceed chlorine acid

Hydrochloric acid is included in this example to illustrate the difference in

names between the "ic" acids containing or not containing oxygen.

6. Hydroxides. Since the hydroxide group is called "hydrogen-oxygen" the term used, for instance, with sodium hydroxide is "hydrogen-oxygen change sodium." The term as expressed in this literal translation sounds clumsy and awkward, but it must be remembered, as was pointed out above, that Chinese is monosyllabic, and hence this expression has only four syllables in Chinese and is shorter than the English term.

7. Salts. The three types are written as below.

normal	lead sulfate	sulfur acid lead
acid	sodium bicarbonate	carbon acid hydrogen sodium or acid property carbon acid sodium
basic	basic lead nitrate	hydrogen-oxygen change saltpetre acid lead[5] or alkali property saltpetre acid lead

If there is more than one acid or basic salt, it is expressed as shown by this illustration.

Na_2HPO_4	phosphorus acid hydrogen two sodium
NaH_2PO_4	phosphorus acid two hydrogen sodium

Organic terms are not discussed in this paper since they have not been used to the same extent as are those of inorganic chemistry. This is due to their greater complexity and the comparatively few organic chemistry text or reference books written in Chinese. Hence organic compounds, save the commoner ones, are usually called by their foreign name (usually English).[6]

From the above discussion and illustrations it is clear that the Chinese language lends itself remarkably well to the creation of a chemical nomenclature. Since this development is quite recent, it has been able to profit by the experience of chemists elsewhere and the universal agreement now reached about the significance of general chemical terms. This, combined with the ideographic nature of the language, its clearness and simplicity of grammar, has resulted in a highly satisfactory nomenclature. At present, in certain branches where progress is proceeding rapidly, the temporary use of foreign terms is unavoidable. But as soon as such terms have been given a standard meaning, they can be readily included by the extension of the present system.

The author wishes to take this opportunity of thanking Miss H. Y. Liao and Mr. H. T. Chiang for their help in preparing this article.

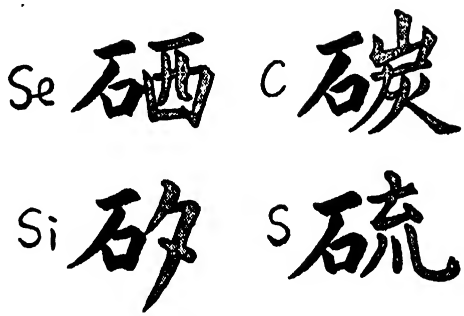

FIG. 5. CHINESE CHARACTERS FOR NON-METALLIC SOLID ELEMENTS WRITTEN TO ILLUSTRATE THE COMMON "STONE" RADICAL.

FIG. 6. METALLIC ELEMENT CHARACTERS WITH THE COMMON "GOLD" RADICAL.

[5] Nitric acid is called saltpetre acid rather than nitrogen acid as a concession to common usage.

[6] It is interesting that of the 25 papers published in the *Journal of the Chinese Chemical Society* for 1941 (vol. 7), 23 are written in English and 2 are in German. Papers written in Chinese are not accepted.

SCIENTISTS AND MACHINERY OF THE STATE

By Dr. CHARLES E. KELLOGG

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As soon as the enormous social implication of science in a modern state is admitted, the great importance of symmetry in science is realized. To be successful, democracy must deal with many problems and many aspects, all relevant aspects, of each problem, because emphasis is placed upon the welfare of the whole group in terms of individual values and opportunities, not alone upon progress or efficiency in some special sphere or upon the material power of the state. In fact, the nearer the democratic state approaches perfection, the more its citizens become citizens of the world. As the individual finds his welfare related to that of his community, and the community to the state, so he finds the welfare of citizens in one state dependent upon the well-being of those in other states.

Thus in the democratic state problems must be conceived in relationship to this total problem, not just the problem of some one science or of some one specialist striving, perhaps, to achieve what he regards as a well-rounded program in terms of his special field. Certainly the scientist is after truth—wherever it is and wherever it leads, but with proper regard to its relevancy.

The achievement of this essential symmetry raises great problems of coordination. This is really another word for planning or for the development of proper balance. Frequently, very frequently, the coordination has been so difficult, that the problem has been "cut-down" or over-simplified, and then "solved," but, of course, the real problem remained where it was.

Since the problem of coordination is so closely related to the task of administration, the two have often been identified. Some go so far as to say that the task of administration is largely one of securing essential cooperation and coordination. Although this view simplifies the problem in terms of simple and customary administrative procedures it is scarcely acceptable. Coordination and administration are overlapping functions, and related functions, but they are by no means identical. As the rapidly growing need for coordination has been realized there has been a perfectly natural, but unfortunate, attempt to solve the problem and harmonize the needs in accordance with older existing patterns of organization—an attempt to fit the problem to the existing, familiar administrative techniques. Less attention has been given to the kind of organization needed to accommodate an attack on the problems.

The existing kinds of administration, with detailed organization, is likely to segregate scientists according to subject matter. Since many problems, especially those of broad significance, require the attention of scientists in several organizational groups, symmetrical programs in either research or in the application of scientific principles are often difficult to arrange. Individual groups are likely to over-simplify problems, vertically, in terms of their particular universe, experience, and techniques; although, of course, not necessarily, since many of the broadest thinkers are also identified prominently with some particular field of science.

Some have suggested a similar kind of organization, but with subdivisions according to problems, rather than according to skills or branches of knowl-

edge. This method leads to a different kind of over-simplification, but one just as serious, because all important problems overlap with others and the identification of a region, a group of people, or any single activity in society with some one problem is very likely to lead to overemphasis and disharmony. In addition, this kind of organization leads to great duplication in research, since the results of fundamental researches are often essential to many problems. Further, intimate association with workers in the same field is as important to the researcher as association with workers in different fields.

An important development has been the establishment of coordinating groups—groups whose function it is to bring people with different points of view and different skills together for the consideration of problems. Likely some additional developments in this direction may be expected. As yet, the relationship of scientists to these groups and to this effort has not been clearly conceived, and their participation not very effective. Partly this is due to a lack of interest, and a shirking of broader responsibilities that so often accompanies specialization. But at the same time the scientist is often unwelcome to these groups, if he brings his scientific method with him. He sees too many sides of a problem, often objects to the simple solution, often refers to facts and principles.

Frequently the coordinator or coordinating groups undertake to define the problem and then tell the scientist his function and how he shall use his techniques in helping develop a solution. If the coordinator is well-informed in the particular field of the scientist, all may go smoothly. But usually he is not well informed, at least not in all fields, and oftentimes he is not trained in any field of science, or even familiar with the nature of the scientific method. Under such conditions the scientist, even the socially aware scientist who is convinced of the need for coordination and planning, finds himself in an impossible position. If he cooperates in the program already outlined or if he undertakes the problem as defined, he may feel almost certain that failure and waste are inevitable. This difficulty cannot be avoided by "voting in committees" where members are of widely different competence. Such voting is not entirely democratic because it is assumed, unconsciously, in the democratic processes, that those voting on a proposal are, theoretically at least, of approximately equal competence as far as the particular proposal is concerned.

In democratic coordination the extremes of autocracy or anarchy must be avoided. Scientists must and will insist upon a voice in the identification and definition of the problems. This is the first and most important essential. There must be reasonable agreement upon the problem and a common understanding of the objectives in both research and the application of scientific principles. Then in the area of his special competence, the scientist must determine how his skills and techniques can be used to best advantage in helping to solve the common problem. Each scientist becomes then, in effect, a coordinator, one of a group whose members have similar competence but in different fields. In this way the extremes of vertical and horizontal over-simplification can be avoided and the essential freedom for scientific inquiry preserved.

For successful planning the scientist must be socially aware, must realize his responsibilities and those of others; and he must refuse to accept a choice between broad thinking and specialization, or between theoretical soundness and practical utility.[1] The scientist who cooper-

[1] Of course, a proposal can be theoretically sound in *one* universe, in one situation, and impractical in *another*, but if practically sound in one it is also theoretically sound, even if the reasons are not clear to everyone.

ates in a preconceived program that he is sure to be unsound may gain a politically useful reputation as a "good cooperator" but he is disloyal to his responsibilities if he remains inarticulate in the democratic state.

Through cooperative study and planning, symmetry in science must be achieved if it is to realize its potentialities for use in a democracy. The maintenance of symmetry is a continual problem. In its simplest form: How shall the scientist select the problems on which he will work? Or stated in administrative terms: How shall the administrators or governing bodies establish priorities for research projects? Certainly individual specialists cannot go along entirely on their own, nor can "fields" be allotted equal funds.

First, there must be some broad understanding of the needs of the people—people as a whole, and of smaller groups, say farmers, workers, tenants, school children, investors, folk in the Great Plains, and other overlapping groups. These must be understood in relation to one another, to general and local economic and social forces, and to the environment. In planning agricultural research, for example, a first question is, what are the limiting factors—what are the things that are preventing our farm people from realizing a fuller life based upon adequate income, health, education, and the other values that must be recognized? Constantly agricultural scientists must be examining, and reexamining the whole field of agriculture and the problems developing on farms if they are to keep their research and their science symmetrical in respect to its function. The same is true in other fields, large and small, with due account taken of their many overlapping relationships. This need for dynamic symmetry extends to fundamental research as well as to that dealing with the application of fundamental principles. If we take a wider view of society as a whole, this kind of examination, by scientists, should extend throughout our culture.

This development of symmetry is a process that has no end—a continuing process, changing to meet new conditions, like the governing process. It isn't like the planning process for a building that precedes a definite period of construction. While planning is going on, people are living, working, and developing new or different things and ideas. In a democracy there can be no blueprinting of a master plan, and postponing separate actions until the "plan" is drawn. Rather planning in a democracy is a dynamic process of bringing into harmony a whole group of processes, through the use of knowledge, to make possible growth and opportunity for individuals. These separate processes in the world are moving rapidly. Although they can't be stopped, they need to be directed and brought into dynamic harmony, while there is time.

The Scientist and Decision

Scientists have a heavy responsibility in a democratic state for discovering and anticipating problems. All citizens have this responsibility—it is one of the duties of citizenship—but scientists who are socially aware have an especially useful rôle to play. As processes develop and change, they must be guided and directed if serious strains in the social order are to be avoided. In our country, too, with such far-reaching differences in environmental conditions from place to place, corresponding differences in social organization must be expected. Cultural uniformity in the United States would be disastrous to many folk. Through a proper balance between national solidarity and local autonomy, essential variations will be preserved, thus adding variety to the culture and strength to the state.

Scientists have the second responsi-

bility of clarifying and examining problems patiently and accurately, but without over-simplification, either vertically in terms of a single discipline or horizontally in terms of superficial generalities. Coordination must be arranged for problems requiring skills in several fields of competence to utilize, not reject, the most detailed knowledge and most refined principles. Above all, scientists must demonstrate the use of the scientific method, the greatest defensive weapon against the slogan, against the totality of a single idea.

As problems arise, decisions in respect to them must be made. Even a decision to do nothing may be just as significant and far-reaching as a decision to do something. In a democratic state the making of decisions is a widely diffused responsibility. Many are made by private persons and groups. The major decisions may be said to be made by the people directly, by their elected representatives, or by the elected administrators or their subordinates. There are, of course, many exceptions. Certain decisions taken by the governing board of a large corporation or trade union may appear to be far more important to the lives of a great many people than most of the decisions made in some elected governing bodies. But the private citizen, the corporation, or the trade union can only make decisions within a frame of reference laid down by law. Similar restrictions of law and tradition apply to all officials of government in the democratic state, although orderly processes are provided for removing or changing these restrictions and an exercise of the ultimate sovereignty of the state.

There are a great many decisions to be made at several levels of government. Presumably these are made in the best interests of the whole people, considering present and future needs, not in the restricted interest of some one group "representing" laborers, farmers, consumers, business men, or producers, or a special industry, section, trade, profession, or class. In a democracy, one of the greatest tasks of statesmen and of government is to reconcile differences among such groups, with due regard to the needs and welfare of individuals, minorities, and the majority. In the whole process of arriving at decisions, through investigation, evaluation, discussion, and compromise, there are many overlapping stages, both inside and outside the government. Scientists have an important rôle, not a dominating or governing rôle, yet one so important that the modern state can not survive without them.

We might take one problem just as an example—the control of soil erosion. A moment's reflection discloses that this problem is partly included in the wider problem of soil use, in conservation, in flood control, in irrigation, in the development of electric power, in forestry, in agriculture, and in other problems. It is more important in some regions than others. It is related to the social philosophy of individuals and groups regarding the soil. In other words, it is a problem that overlaps many others of equal, less, or greater importance, and cannot possibly be solved without regard to them. Nor is it new. Nor is there a solution to be adopted, once and for all.

Many citizens have been calling attention to this problem. Among these were scientists who studied soils, sought out the laws of their genesis and their changing relationships to plants and land-use practices. They studied the causes of erosion and its effects, and how it might be avoided. These studies are being continued by economists, geologists, engineers, agronomists, and many others beside soil scientists.

A few of these scientists were attached to national institutions of government, many were in state research stations,

while others worked as private citizens or in private institutions. Many recommendations were developed and carried out, but the problem seemed to call for special action by the social group—the government. Their efforts and discussions, as well as those of others brought the matter to the attention of other citizens, including elected officials and legislators.

These representatives decided to do something about the problem. In this decision itself the scientist is primarily a citizen. His original task was one of anticipating and clarifying the problem. But the decision of doing something about it involves competition with many other problems outside of his special field of competence. Such things as national defense, public health, education, maintenance of employment, and a balanced price structure, for example, to mention a few, many of which are of even more vital concern now, compete for appropriations. Thus this first decision to do something about it is made in a very broad frame of reference, or should be in a democracy.

After this general decision come others. How vital is the problem in relation to others? And how much effort should be directed to this one? How can soil erosion be controlled? Should the problem be attacked directly, or is it more an indication, a symptom, of some other problems?

Immediately, the thoughtful legislator and administrator can see that there are many ways toward a solution of the problem, and that several activities may contribute. Research for the development of new farm practices as applied to particular soil types, together with a wider dissemination of existing and new knowledge, in an educational program for farmers and other land users, is one way. This program is very flexible and might include farm or community demonstrations. As another approach, governmental agencies can be supplied funds for doing the work on the land with hired personnel. This can be done through central agencies or through grant-in-aid to local governments. Land-users may be given much or little responsibility in deciding what is to be done and in doing it. Again land-users may be paid subsidies for good practices, or they may be subject to penalties for poor ones. Local districts may be established as new agencies of government, or existing governmental agencies may be utilized.

These are a few of the alternatives. Here again scientists have a responsibility. They can predict, better perhaps than other citizens, the relative effectiveness of these different methods, their cost, and the administrative difficulties involved. That is, socially aware scientists who have kept their science symmetrical can. Having done this accurately and carefully, it is again not up to them as scientists to make the final decisions regarding which method or combination of methods shall be followed.

These decisions must take account of citizen opinion and how the several alternatives may influence other programs in agriculture, forestry, conservation, and flood control, other important objectives, and other values. The administrator who decides, or helps decide, may be a person with scientific training, may possess scientific knowledge, but it is not primarily in his capacity as a scientist, in the sense of an expert, that he exercises this judgment, but rather in his capacity as a citizen, with special responsibilities in the government of a democratic state.

It is thus through the use of scientific principles and the scientific method that social policy may be formulated and followed by action in a democratic state. Without using science to the limit and without arriving at decisions through a process that insures broad consideration,

and with speed where speed is essential, the inconsistencies in our culture will become sharpened and the cracks in the social organism will be widened. Especially now there is much work to be done to develop a more adequate use of science, while there is time.

Science and Liberalism

Broadly speaking, this discussion has been pointed toward a closer fusion of science and liberalism. Both concepts have a great deal in common. The scientific thinker stands midway between the dogmatist who entertains no doubts at all about the validity of his views and the extreme skeptic who believes nothing. To the scientist truth is a matter of greater or lesser probability. The liberal thinker stands midway between the extreme conservative who holds strictly to the status quo and the extreme radical who sees little or no good in the present. Democracy is the institutional expression of liberalism, midway between total authoritarianism and anarchy. In one sense, these three concepts—science, liberalism, and democracy—are relatively fixed, as far as conceptual ideals are concerned; yet in respect to the real world of things, ideas, purposes, actions, and processes, they are dynamic, changing concepts.

Liberalism in a democracy implies liberalism in ideas of morals, justice, art, and science. Science is concerned primarily with the relationship of facts to facts—how nature behaves, including man himself as a part of nature. The evaluation of the facts and principles of science in terms of social values can not be accomplished within the field of science alone, but only in the wide cultural atmosphere of all human ideas and values. Science and liberalism are mutually essential to one another. Without facts and an understanding of their relevancy, liberalism becomes empty, ineffectual, and futile; and without freedom for expression and criticism, for trial, error, and correction, science decays.

The American democracy was developed out of the same spirit of liberalism and freedom of thought that nourished science and laid the foundation for its modern development. Yet the early pattern of democracy was conceived when science was only beginning and before its material results became so important. Since that time, science has been accepted gradually and unevenly in modern society. The older forms and expressions of democracy are even used to support prejudices against changes that are seen, from the facts disclosed by science, to be essential for democracy. Many ideas that were liberal or scientific at the time the principles of American democracy were committed to paper 150 years ago, are not so regarded to-day, although the fundamental objectives of democracy and the principles of the scientific method have changed but little.

Some have confused conflicts between some particular *form* of democracy and certain principles of science, with a general conflict between the two concepts. They differ, and they overlap; but each supports the other. Yet in practice there are conflicts in modern democratic states that threaten their very existence, conflicts that can be resolved through the application of the scientific method in a steady framework of liberalism.

Liberalism, like science, must be symmetrical for effectiveness. A burning heart, filled with emotional sympathy for troubled people, is not enough. The liberal who avoids the task of informing himself can not expect to accomplish much. No man can fairly call himself a supporter of democracy who avoids this task, where opportunities are available. Liberalism without science becomes a sloppy sentimentalism. It expresses itself in whimpering or shouting

where calm thought and objectivity might be successful.

There is a failure to distinguish between charity and opportunity, between the lazy and the unemployed, between freedom and license, between carelessness and miscalculation, between privilege and responsibility, and between failures of the individual and failures of the state. Even the "good" man must sometimes fertilize his corn, spray his fruit trees, insure his house, and discipline his children.

Science without liberalism leads to efficiency conceived in narrow, materialistic terms—but an efficiency coldly silent about human values and ultimate goals for either the individual or society. It leads to a philosophy of survival of the strongest and the luckiest. In the commercial field, for example, because the housewife or farmer fail to judge the worth of a machine they legally buy, they must be penalized severely. Even though good becomes what is practical, the practical is measurable in physical terms. Art becomes decorative rather than inspirational. Man serves the machines, lives for the gadgets that were to serve him. Such a philosophy of material efficiency leads to suppression of those flights of fancy that gave it birth. The inventor's machine finally destroys the free spirits from whence his knowledge came.

Science without liberalism would lead us quickly to disaster, while liberalism without science might bring us more slowly to decay. Given the two concepts, dominant together, our people can find strength and happiness. Scientists have a large responsibility to help bring together the principles of science and those of democracy—to revitalize democracy as a dynamic pattern of social organization within which all may find opportunity and justice. Up to now they have scarcely taken the trouble. A great deal depends upon whether they do so in the future while there is time.

UTOPIAN DELUSIONS

To some who view the present chaos in the light of the follies of the last twenty years no small measure of blame must be laid at the door of the prevalent Utopian philosophy. One has only to recall the slogan, "war to end war" and the famous pact to outlaw war to illustrate the point. Surely the history of the United States from 1917 to 1941 shows the Utopian philosophy may defeat the very movements it would foster. Dreams based on a misconception of a total situation are bound to produce a secret reaction. When impossible ideals are set before men's minds, no harvests except bitter disillusionment and cynicism can be expected.

The danger exists again to-day. We are fighting to defend human liberty and render secure the American way of life. We desire to prevent the recurrence of a devastating world-wide struggle every generation. We want and expect to have the United States a better place to live in when the war is over. Limited objectives we must set. But let us proceed cautiously in painting too rosy a picture of the world or even the United States after the war is over. To my mind, the Utopians who foresee the future in terms of a world made perfect by technology and the applied social sciences, or those who believe in a complete spiritual regeneration of a majority of men are equally mistaken.

The facts of history and of human nature to me speak of a universe constructed on totally different principles. The problem of evil seems to be ever present as the air we breathe. Why this should be, I do not pretend to know; nor do I believe that man will ever fully understand, though he must never cease to try. In terms of my faith, it is unthinkable to say, as some have said, that men died in vain in certain wars because the proclaimed objective was never won. To me, whether a man lives or dies in vain can never be measured by the collective activity of his fellows, never by the fruits of war or peace. It can be measured only by the way he faces his own problems, by the success or failure of the inner conflict within his soul. And of this no one may know save God.—*Baccalaureate Sermon; James B. Conant, President of Harvard University.*

BOOKS ON SCIENCE FOR LAYMEN

AIRPLANES—PAST AND PRESENT[1]

WHETHER the airplane is considered a blessing or a curse to the human race, its ever-increasing influence in human affairs can not be denied. The coming of the present war brought the airplane as a harbinger of suffering and death to the civilian population, to innocent women and children, and made war as never before total war. To-day for us the airplane assumes the aspect of the major offensive weapon by means of which victory is ultimately to be achieved. Bigger, faster and better, they roll from the long assembly lines to travel to the far corners of the world.

When one inspects the intricate assembly of mechanisms and structure in a modern long-range bomber, he marvels at the ingenuity and skill of the mind that comprehends the functions and methods of operation of the parts. The intelligence required to create it seems beyond the power of men. As with most scientific achievements, this appraisal is based on an illusion, for the airplane in its present form is a creation not of one mind but of many minds. It has roots in the past, and its present state of development can be appreciated only by studying its history, its step-by-step development from a mere dream to its present stature.

Mr. Black's non-technical narrative account of the development of the balloon, airship and airplane gives the historical background required for appreciating these products of painstaking scientific investigation and experiment. A careful reader of his book will come to comprehend that the airplane was not invented full-fledged by any one individual, and that its continued improvement rests on the efforts of many scientists and engineers in different fields working together.

Mr. Black tells of the countless centuries of mythology preceding the period of engineering and scientific development, of Daedalus and Icarus, of Roger Bacon, Da Vinci and De Lana, of the discovery of hydrogen in 1766, of the Montgolfiers' hot-air balloon and Charles' hydrogen balloon in 1783, of the development of the rigid airship. Interspersed with these accounts are descriptions of Cayley's experiments, of Henson's "Ariel" and Stringfellow's models, the whole occupying three chapters of the twenty-two and twenty-eight of the 267 pages in the book. This brief summary of three chapters illustrates the general method of treatment. The treatment is not encyclopedic but accomplishes the author's purpose of creating mental pictures of each period.

The appraisal of the work of Langley and of the Wright brothers is unusually accurate for a popular account. Langley is included with Maxim and Clement Ader as the three who nearly succeeded, and the accomplishment of the Wright brothers forms the subject of Chapter VI under the heading "Mechanical Flight at Last." Good judgment has been used in the accounts of other controversial matters such as the patent suits, the production scandals of World War I and the warship bombing controversy.

The book covers the period down to the beginning of World War II. Included within its pages are numerous accounts of beneficial contributions to human happiness and welfare. Like all physical creations of science and technology, the airplane in itself is neither good nor evil and has no moral attributes. It is a tool which can be used by human intelligence for good or evil purposes and Mr. Black's book is a faithful record of the manifold purposes for which it has been used in the past from "ballyhoo" at county fairs to fast transport of goods and passengers.

HUGH L. DRYDEN

[1] *The Story of Flying.* A. Black. Illustrated. xxii + 267 pp. $2.75. April, 1940. McGraw-Hill Book Company.

THE PHILOSOPHY OF ALFRED NORTH WHITEHEAD[1]

THE volume is the third of a unique series entitled "The Library of Living Philosophers," following after two similar publications on John Dewey and George Santayana. Noteworthy indeed is the purpose of the editor of the series; it is to select philosophers of competence with interests akin to those of the great thinker whose works are under discussion, and assign to them the task of critique and query while the venerable subject is living and capable of answering his critics. The results are then collected in a single volume which is to be handed to posterity, an authentic document on the thought of a great philosopher. In the present instance, the execution of the plan almost equals its brilliant conception; the shortcomings are not the fault of editor or authors: they lie in the regrettable fact that a serious illness prevented Professor Whitehead from making specific replies to his critics.

The book contains, first of all, fourteen pages of autobiographical notes by Whitehead, simple remarks which by their candor and factualness strike at the heart of the reader. Then follow eighteen scholarly articles by V. Lowe, W. V. Quine, F. S. C. Northrop, E. B. McGilvary, J. Needham, P. Hughes, W. M. Urban, A. D. Ritschie, A. E. Murphy, W. E. Hocking, R. W. Sellars, J. Goheen, B. Morris, J. S. Bixler, C. Hartshorne, P. A. Schilpp, H. W. Holmes and John Dewey. None of them is a mere résumé of Whitehead's philosophy; each brings forth new fundamental ideas suggested by the work of Whitehead, each questions earnestly the validity of some feature or other of his writings, each author endeavors to amalgamate Whitehead's views with his own. As one reads on, there grows in one's mind an acute regret that circumstances should have made impossible detailed answers to so imposing an array of significant and sympathetic questions. But the sense of frustration is at least partly destroyed when the reader finds, at the end of the volume, two summarizing articles from Whitehead's pen, the second of which will rank among the most memorable of his writings. They are entitled "Mathematics and the Good" and "Immortality." At the end there is a fairly complete bibliography of Whitehead's writings.

No specific reason need be offered for recommending a book on philosophy to scientists. But it does seem relevant to remark that Whitehead was, first of all, a scientist and that his philosophy is the sublimation of the experiences of an active and brilliant mathematician.

HENRY MARGENAU

[1] *The Philosophy of Alfred North Whitehead.* Paul A. Schilpp, editor. xviii + 745 pp. Illustrated. $4.00. 1941. Northwestern University Press.

CONDITIONED REFLEXES AND PSYCHIATRY[1]

THIS Volume II of Pavlov's work on conditioned reflexes adds sixteen chapters to Volume I, published in 1928. From Dr. Horsley Gantt's introduction we learn that the two volumes represent "the only complete collection of Pavlov's lectures on conditioned reflexes and psychiatry in any language." For this enrichment of the physiological and pathophysiological, psychological and psychopathological literature, scientific workers, particularly English-speaking scientific workers, owe a debt of gratitude to Dr. Gantt, translator, interpreter and exponent of Pavlov's work.

In the present volume Pavlov interprets psychological concepts, psychoneurotic and psychotic reactions in terms of conditioned reflexes. These are identified with what associative psychology calls association. Both, conditioned reflex and association, represent two aspects—physiological and psycho-

[1] *Conditioned Reflexes and Psychiatry.* Ivan Petrovitch Pavlov. Translated by W. H. Gantt. Illustrated. 199 pp. $4.00. May, 1941. International Publishers.

logical—of the same phenomenon, that is, perceptions and reactions associated with coincidental, though under the circumstances unessential factors, may be spontaneously evoked by one or more of the incidental factors. The fact that a well-established conditioned reaction may serve as an unconditioned stimulus for the formation of a new conditioned reaction makes it still more obvious that the identity of the concepts of association and conditioned reflex is complete. In one of his last writings, if not the last, Pavlov expressed his pleasure at the recognition by associative psychologists that conditioned reflexes provide a firm basis for associative psychology.

In accordance with the classical subdivision of the anatomy and physiology of the C.N.S., Pavlov speaks of: (1) *The lower nervous activities, i.e.*, activities necessary to maintain life and carried out by the vegetative subcortical centers. These vegetative functions are called *unconditioned* and stimuli provoking them are *unconditioned* stimuli. (2) *The higher nervous activities*—controlling behavior—have their seat in the cerebral hemispheres. These are *conditioned reactions* caused by *conditioned stimuli*.

The fundamental physiological processes of the whole C.N.S. system are those responding to excitation and inhibition, both of which under certain conditions may be provoked by the same stimuli; and both of which are subjected to the laws of irradiation, concentration and interaction.

With these basic physiological notions, supplemented by the recognition of the role of constitutional endowment and by very accurate and abundant observations in animal studies, Pavlov had tried to throw light on the mechanism of human neurotic and psychotic reactions. The common denominator in various abnormal mental reactions lies in impairment of the normal balance between nervous excitation and inhibition. Thus, the main factors causing neuroses are: Too strong or too complex stimuli; predominance of inhibitory processes; collision between excitation and inhibition processes. In schizophrenic conditions the primary trouble lies in the weakness of the C.N.S., particularly of the cortex. The weak nervous system reacts to environmental difficulties readily with fatigue. The organism protects itself against undue or excessive fatigue in making appeal to the inhibitory processes of the cerebral hemispheres; when sufficiently inhibited, the cortex loses control over the subcortical function. The progression of inhibition ultimately culminates in a chronic state of hypnosis. Thus, Pavlov reaches the conclusion that "schizophrenia in certain variations and phases actually represents chronic hypnosis."

It appears highly doubtful either that Pavlov's physiological interpretations of psychological and psychopathological phenomena are illuminating at the present state of our knowledge or that they are paving the way for further fruitful investigations. But the perfect experimenter, as Pavlov was, unintentionally teaches us a great lesson: and that is that dogmatic adherence to one concept in trying to understand complex and heterogeneous phenomena is conducive to sterile speculation. What Pavlov has failed to see is that analysis pushed to the extreme does not necessarily help to understand the analyzed "whole," which, on the other hand, lends itself for studies with methods and procedures—other, than laboratory physiological ones—respecting the integrated function of the "whole."

These critical remarks are not intended to convey the impression that the book is not worthwhile reading. The contrary is the reviewer's opinion. Gantt's Introduction offers a particularly valuable historical survey of the last few years of life of Pavlov. It also presents a review full of sound interpretations and constructive criticism of the essentials of Pavlov's life work.

S. Katzenelbogen

BRONZE BUST OF THE LATE HENRY FAIRFIELD OSBORN

UNVEILED AT CEREMONIES DEDICATING THE NEW NORTH AMERICAN MAMMAL HALL OF THE AMERICAN MUSEUM OF NATURAL HISTORY OF WHICH OSBORN WAS PRESIDENT FROM 1908 UNTIL HIS DEATH IN 1935. HE WAS ELECTED PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN 1913, AND WAS A MEMBER OF THE NATIONAL ACADEMY OF SCIENCES AND NUMEROUS OTHER AMERICAN AND FOREIGN SCIENTIFIC SOCIETIES. THE BUST IS THE WORK OF JOY FLINCH BUBA.

THE PROGRESS OF SCIENCE

FRANKLIN MEDALISTS FOR 1942

Two men whose achievements have contributed notably to important war industries were chosen as the recipients of the Franklin Medal this year. At the Medal Day exercises of the Franklin Institute in Philadelphia the medals were presented by Charles S. Redding, president of the institute, to Paul Dyer Merica and Jerome Clarke Hunsaker.

Dr. Merica is a metallurgist of world-wide distinction. He received the degree of doctor of philosophy from the University of Berlin, and shortly afterwards joined the staff of the Bureau of Standards in the newly created division of metallurgy under Dr. George K. Burgess.

Shortly after the last war Dr. A. Wilm had developed duralumin by melting suitable mixtures of copper and aluminum. This alloy when quenched from a temperature of about 500° C and tested without delay, showed only moderate hardness and strength. But after standing a few days at room temperature, the same tests revealed that hardness, strength and ductility increased from 30 to 50 per cent. This strange behavior of duralumin attracted Dr. Merica's attention. His subsequent researches into its problems resulted in his advancing a daring hypothesis concerning the process of hardening after quenching.

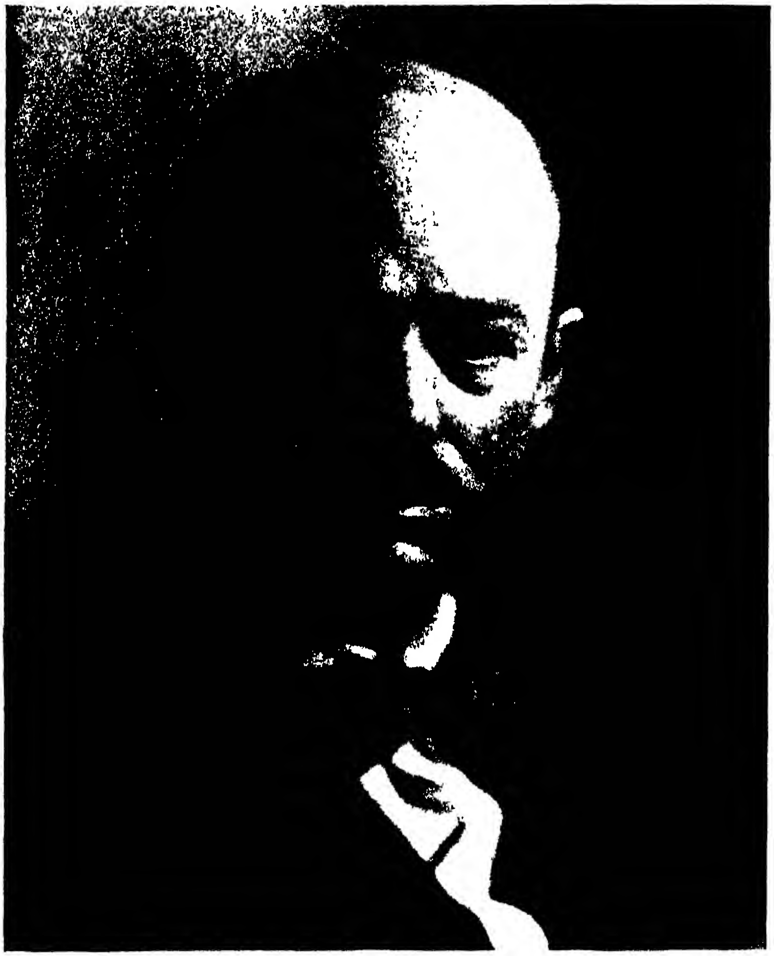
The opinion prevailing at the time was that the hardness condition of an alloy was that of its solid solution. Dr. Merica suggested that the hardness of the solid solution might be increased by a partial decomposition. He concluded that the cause of the increased hardness of duralumin brought about by aging at room temperature was the partial decomposition of the alloy resulting in the precipitation of minute particles of the binary compound $CuAl_2$. During the process of aging, particles of the binary compound extricate themselves from the solid solution and attain positions such that the internal stresses upon them are in equilibrium, hence they are hard to dislodge when mechanical stresses are applied to the whole mass, thereby giving to it the properties of strength and hardness.

He continued his work on other aluminum alloys and extended his field of research to include the alloys of nickel and cast iron. He also devised a method of heat treatment which improved many alloys not regarded as capable of improvement by heat treatment. His success in adapting many alloys to commercial uses has been quite as distinctive as his discovery of precipitation hardening.

Dr. Merica is the author of several books of recognized originality and merit upon metallurgical subjects. He is now vice-president of the International Nickel Company.

The second Franklin Medal of the year was awarded to Jerome Clarke Hunsaker, head of the department of mechanical engineering, Massachusetts Institute of Technology, and chairman of the National Advisory Committee for Aeronautics. After a brilliant career at the U. S. Naval Academy, Dr. Hunsaker was assigned to the Corps of Naval Construction and was sent by the Navy Department to the Massachusetts Institute of Technology, from which he graduated in 1912.

He spent the following year in Europe studying the dynamical stability of airplanes, paying particular attention to the technique of wind tunnel testing, at the National Physical Laboratory in London and at the Eiffel Laboratory in Paris. Upon his return to this country he convinced the authorities of the Massachusetts Institute of Technology of the importance of this new technique and personally superintended the construction of a wind tunnel. He then, at the age of 28, established the first college

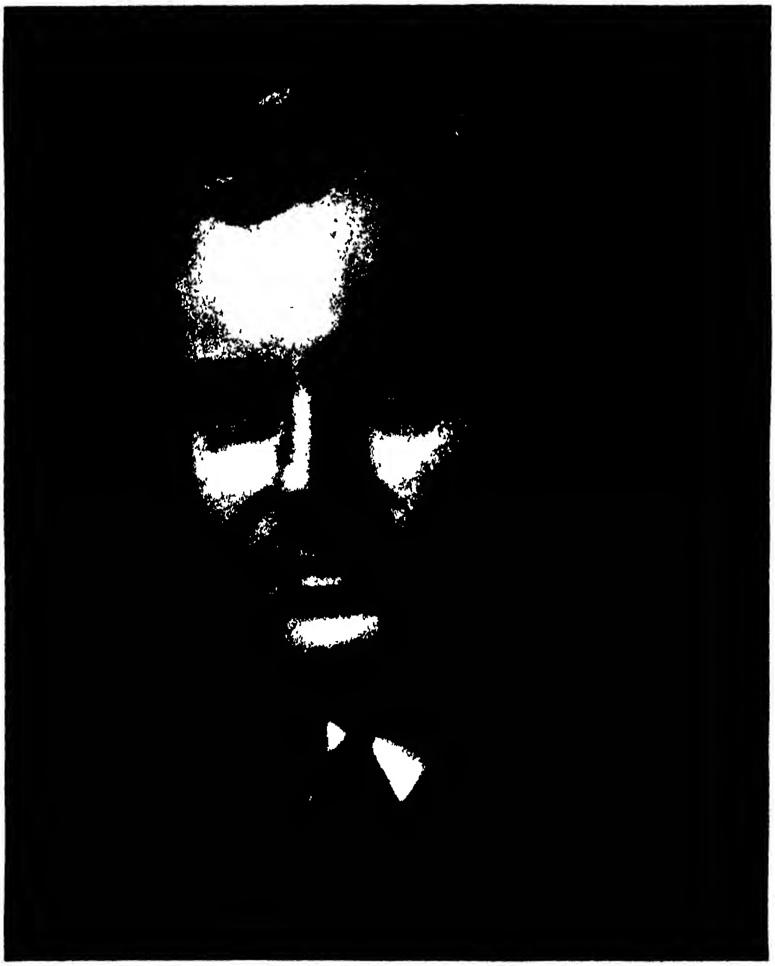


DR. J. C. HUNSAKER

course in the United States devoted to aerodynamics and airplane design.

The Navy Department appointed him head of the Aircraft Division of the Bureau of Construction and Repair, and Dr. Hunsaker thus became responsible for the design, construction and procurement of naval aircraft during the first World War. It is interesting to note that he was one of the first to appreciate the usefulness of duralumin in the field of aeronautics at about the same time that Dr. Merica was developing his theory on precipitation hardening of this alloy.

Dr. Hunsaker has left an indelible impression upon the aeronautical science of the generation which has witnessed its greatest advances. His contributions to the science have been manifold and various. Some of his more noteworthy achievements have been the design of the NC type of flying boat (one of which made aviation history on its transatlantic flight in 1919); the design of the first large airship (the *Shenandoah*) made in this country; the development of launching catapults and arresting gear for deck landings on airplane carriers; the design of light planes for ser-



DR. PAUL D. MERICA

vice on carriers; the design of an air-cooled radial engine; and the development of a gas-proof fabric for airship construction.

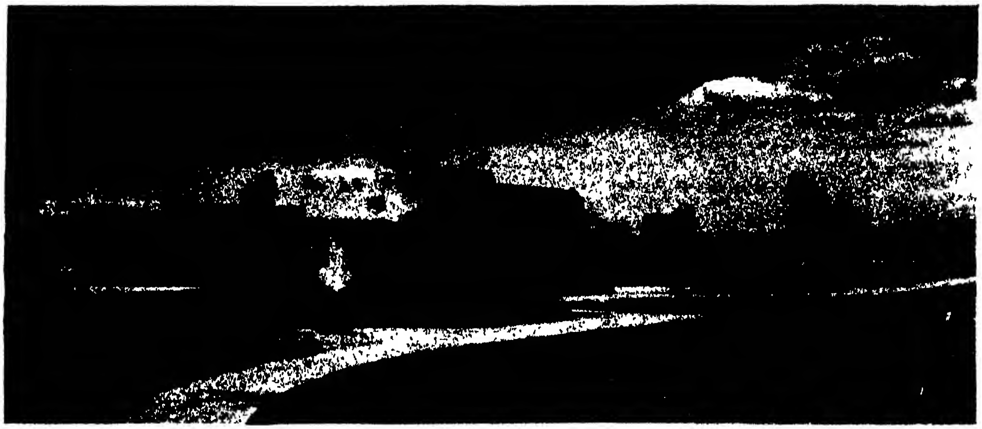
In 1920 he was awarded the Navy Cross with the following citation:

For exceptionally meritorious service in a duty of great responsibility in charge of the Aircraft Division of the Bureau of Construction and Repair, in which position he showed ability unsurpassed in the United States as an aircraft designer as well as great organizing and executive ability in expanding and handling a large force. The successful development of naval aircraft was due largely to the ability and industry of this officer.

HENRY BUTLER ALLEN,
Secretary and Director
THE FRANKLIN INSTITUTE

MEETING OF THE SOUTHWESTERN DIVISION OF THE AMERICAN ASSOCIATION

Is it wise to hold scientific meetings during the duration of the war? The reasons given for abandoning them include the difficulty of automobile and railroad transportation resulting from rationing of cars, gasoline and tires, and



National Park Service

ADMINISTRATION BUILDING AT THE WHITE SANDS NATIONAL MONUMENT

THE VISITING SCIENTISTS HEARD TALKS ON THE WHITE SANDS IN THE PATIO OF THIS BUILDING.

the urgent need of space on railroads and airplanes for the transportation of troops and government employees. Some people argue that scientists are too busy with secret war work to take the time to attend meetings. Others say that the extra burdens placed on college teachers and industrial research workers make it impossible for them to carry on any but the most urgent scientific activities.

The recent meeting, April 28–30, of the Southwestern Division of the American Association for the Advancement of Science gave some interesting sidelights on the above question. Eighty-seven papers were presented in the fields of physical, biological, mathematical and social sciences in spite of the fact that the division has a membership of less than four hundred in the American Association. About 40 per cent. of the titles were presented by the faculty and students of the New Mexico State College of Agriculture and Mechanic Arts, which served as host institution. Some were presented by young men who had never had the opportunity of attending a large scientific meeting. They were

National Park Service

THE WHITE SANDS AND SAN ANDRES MOUNTAINS

THESE VAST SAND DUNES OF WHITE GYPSUM EXTEND OVER 600 SQUARE MILES.

not only thrilled by the occasion, but obtained valuable experience in the preparation and presentation of their work. There were papers having a more or less direct bearing on our war and post-war program and included such titles as "On the Anatomy of the Guayule," "Sales Tax in a Victory War Program" and "A Preliminary Examination of Some Proposals for World Reconstruction."

The men who are to-day engaged in semi- or non-war scientific work will to-morrow furnish the reserve from which our government and industries will draw their highly trained man power. This reserve must be kept intact by constant replacement. One conclusion which can be drawn from the above observations is that it is occasionally necessary to bring scientific meetings to scientists rather than scientists to meetings.

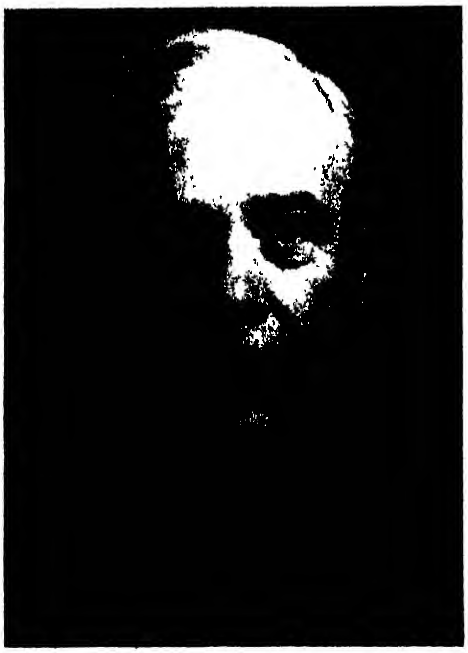
The meeting opened officially with an address of welcome by Dean Branson, acting president of the college in the absence of President Milton, who is on leave as an officer in the Chemical Warfare Service. The response was given by President Craig of the association. A great impetus to the problem of conservation was given in 1933 as the result of the selection of Aldo Leopold to give the fourth John Wesley Powell Lecture in Las Cruces on the occasion of the first Las Cruces meeting. Dr. Leopold discussed the general problem of soil erosion and its correction as related to the conservation of plant and animal life. Since that time the Southwestern Conservation League has been very active and has been largely guided by Dr. John D. Clark, professor of chemistry at the University of New Mexico. At the noon luncheon on Monday, Dr. Clark delivered a paper on "Conservation since 1933," in which he reviewed accomplishments since Dr. Leopold's visit.

National Park Service

YUCCA IN BLOOM ON THE EDGE OF THE WHITE SANDS

Following the evening dinner sponsored by the American Association of University Professors and Sigma Xi, Dr. Donald D. Brand, of the University of New Mexico, spoke on "Observations on Certain South American Economies," in

HADLEY HALL
ON THE CAMPUS OF THE NEW MEXICO STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS.



DR. H. P. MERA
NEWLY ELECTED PRESIDENT OF THE SOUTHWESTERN DIVISION OF THE ASSOCIATION; ARCHEOLOGIST, LABORATORY OF ANTHROPOLOGY, SANTA FE.

which he attempted to explain some of the causes of misunderstanding between the nations of the two continents. On Tuesday evening Howard W. Blakeslee, science editor of the Associated Press and joint winner of the Pulitzer prize in journalism in 1937, delivered the Thirteenth John Wesley Powell Memorial Lecture in the Branigan Memorial Library in Las Cruces, on the subject "Science Moves Ahead." These lectures were established in 1929 in honor of the noted explorer of the Grand Canyon. Under present arrangements the lecture is presented to the community in appreciation of its encouragement and support of the meeting. The person chosen to deliver the address is a distinguished scholar in his field, and is at liberty to speak on a topic of his own selection.

On Tuesday afternoon a caravan carrying seventy persons left Las Cruces for the "White Sands National Monument" near Alamogordo, New Mexico. The monument consists of vast "sand" dunes of snowy white gypsum covering an area of more than 600 square miles. Near the front of the sands, which advance from two to twenty feet per year, vegetation thrives, but back in the interior there is not a trace of vegetation to mar the dazzling white. Custodian Johnwill Faris welcomed the party, after which Dr. W. B. McDougall, of the Park Service, gave a talk on the "History and Development of White Sands National Monument" in the patio of the Administration Building. This was followed by a talk on "Gypsum on Tour" by Dr. S. B. Talmadge, professor of geology at the New Mexico College of Mines at Socorro. A concluding talk was given on "Some Biological Relations of the White Sands" by Dr. F. W. Emerson, professor of biology at the New Mexico Highlands University at Las Vegas. Dr. Emerson's talk was given

AERIAL VIEW OF THE NEW MEXICO STATE COLLEGE

after the party had been taken some distance out among the dunes, where he had the material for his discussion easily available. The caravan then proceeded to the barren interior, where nothing but the sands were visible. The scientists, with wives and children, amused themselves climbing the dunes and sliding down the steep fronts, and had no difficulty working up a good appetite for the delicious "chuck wagon supper" which was being prepared.

Wednesday noon a strictly Spanish luncheon was served at "La Posta" in Old Mesilla. Following the luncheon Dr. Fabian Garcia, director of the New Mexico Agricultural Experiment Station, told of many incidents of historical

FOSTER HALL, NEW MEXICO STATE COLLEGE

interest in connection with "La Posta," Old Mesilla and the "Billy the Kid Museum." This was followed by music and dancing by Spanish-American senors and senoritas in the patio of La Posta. Following the closing section meeting on Wednesday afternoon the U. S. Bureau of Plant Industry conducted a tour in which cotton, guayule and cactus were the principal topics of interest. The meeting came to a close officially with a banquet and the address "the Rôle of Spectrography in National Defense" by retiring President Wm. M. Craig, professor of chemistry at the Texas Technological College at Lubbock.

Persons remaining on Thursday were offered a choice of trips to the Jordana Experimental Ranges of the New Mexico College of Agriculture and Mechanic Arts and of the U. S. Forest Service, to the Organ Mountains to observe the native flora and fauna, to the newly discovered Conkling Cave at Bishop's Cap Mountain, or to the city of El Paso, Texas, and Juarez, Mexico.

At the annual business meeting, Dr. H. P. Mera, of the Laboratory of Anthropology at Santa Fe, was elected president, Professor F. H. Douglas, of the Denver Art Museum, was elected vice-president, and Drs. Wm. M. Craig and E. W. Haury were elected to serve on the executive council.

FRANK E. E. GERMANN,
Secretary-Treasurer

A SCIENTIFIC MEETING CANCELLED

A SUMMER meeting of the American Association for the Advancement of Science was scheduled to be held at the University of Michigan, at Ann Arbor, from June 22 to June 25. Programs were being organized by the sections of the association and by various of its affiliated societies until early in March, when it was suddenly announced that the meeting had been cancelled.

There was no reluctance on the part of the University of Michigan to act as host to the association. It had splendid facilities to offer. Its Wrackham building would have provided admirable headquarters; its many lecture halls, excellent meeting places; its dormitories, convenient living rooms. It is a great scientific center. Nearly all the leading scientists on its faculty are members of the association, and Dr. Malcolm H. Soule, chairman of the Hygienic Laboratory and professor of bacteriology, is secretary of the association's Section on Medical Sciences.

The association desired to meet at Ann Arbor. Not only is the University of Michigan a great institution, but it is within easy reach of the many endowed universities and colleges and other state universities of the Middle West. Moreover, Ann Arbor is near the center of a great manufacturing area in which there are numerous large industrial laboratories whose technical staffs include many members of the association. Yet the proposed meeting was cancelled.

The maturing plans of scientific societies and of scientists were set aside indirectly because of what was taking place in Europe, Asia, Africa and the East Indies and on the oceans. World events made it necessary for the university to change radically its academic schedule, to initiate early in June a three-term yearly program instead of two semesters with a long summer vacation. The term beginning in June will continue until the end of September; the next will promptly follow and continue, with a week's vacation at the Christmas holidays, until the end of January; and the third will extend from February until the close of May. Similar reorganizations of academic schedules and of courses are taking place all over the land.

These interruptions of the smooth flow of academic routine may be irritating,

but they are being made for serious purposes. Perhaps the usual distribution of time between periods of work and of vacation in universities has been based too largely on what would be most enjoyable to faculties and students rather than on what would be most useful to the institutions or to society. Perhaps, on the contrary, the drawing of scholars from the relative seclusion in which they have sought out and attempted to transmit to others the great achievements of the human mind will retard the progress of civilization. Evidently no simple statement can describe what is now transpiring in science and education and no one can foresee what the consequences will be.

It is clear, however, that educational institutions must now examine the whole subject of values as never before. Problems of the war are forcing them to do it. Already they are revising their objectives and their methods of attaining them. The problems that will follow the war will force them to reconsiderations of any conclusions they may reach at present, for what is advantageous is advantageous relative to an environment rather than in the abstract, and the environment then will be entirely different from what it has been in the past or is at present. It may well be that the conclusion will be reached that educational institutions have been coasting on the great momentum they acquired in the early decades of this century when technological applications of science produced great wealth and provided unparalleled leisure, without at the same time imposing the stern discipline of new ideals.

At the moment the scientists who were planning to attend the meeting of the association in Ann Arbor are disappointed, but the plans for the New York meeting beginning next December 28 are going steadily forward. It takes such minor irritations as the cancelling of a meeting to arouse men to note the changes that are going on in the world.

F. R. M.

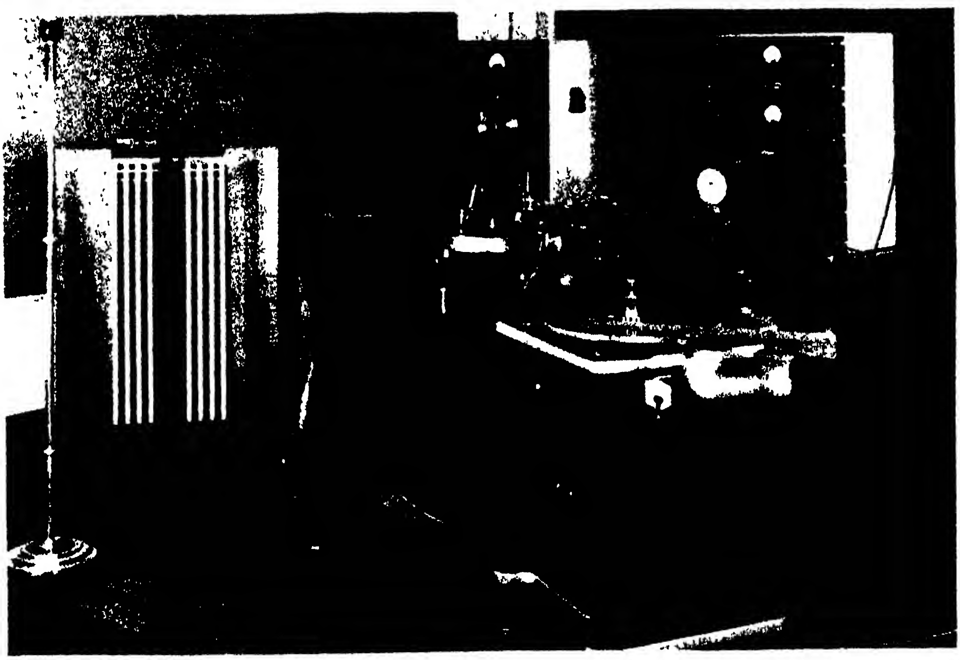
AMERICAN INDIAN SOUND RECORDINGS IN THE NATIONAL ARCHIVES

R. D. W. Connor, archivist of the United States, has announced the receipt of a gift of $30,000 by the National Archives Trust Fund Board, established by a recent Act of Congress. The gift is a contribution from Mr. and Mrs. Hall Clovis, to be used "for transferring the Smithsonian-Densmore Collection of American Indian sound recordings to a permanent base from which service copies can be made." Mr. and Mr. Clovis became interested in this undertaking through George W. Blodgett, eminent sculptor of Indian subjects and secretary of the National Gallery of the American Indian, of which Mrs. Clovis is vice-president, a national organization devoted to disseminating information on the American Indian and "presenting him, his arts, crafts and culture to the white man as a living creative force." The work will be done under the direction of John G. Bradley, the representative of that organization for the District of Columbia, and chief of the Division of Motion Pictures and Sound Recordings in the National Archives.

The Smithsonian-Densmore Collection, said to be the largest of its kind in existence, was transferred to the National Archives by the Smithsonian Institution in March, 1940. It comprises more than 3,000 items of religious, social and tribal music of 76 American Indian groups whose habitat extends from Alaska to Mexico. The recordings cover a period of over 40 years, the earliest date established being 1893. They were made for the most part by ethnologists and collaborators of the Bureau of American

FRONT VIEW OF THE NATIONAL ARCHIVES BUILDING
THE BUILDING WHICH HOUSES THE SMITHSONIAN-DENSMORE COLLECTION.

Ethnology in Indian camps and at Indian ceremonies. The greater number were made by Frances Densmore, American musicologist. Other collectors were John P. Harrington and John R. Swanton, at present members of the staff of

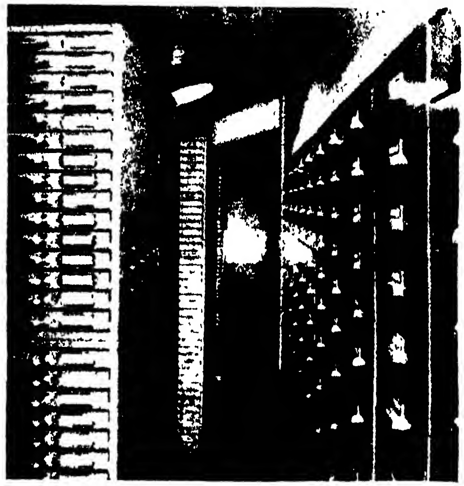


EQUIPMENT USED IN REPRODUCING COPIES OF INDIAN SONGS

the Bureau of American Ethnology; Alice Fletcher, assistant in American ethnology at the Peabody Museum, Harvard University; Francis La Flesche, son of an Omaha Indian chief and himself then a member of the staff of the Bureau of American Ethnology; Jesse W. Fewkes, the "Dean of American Archeologists"; Thurlow Lieurance, composer and musician, and others.

Inasmuch as the recordings are on perishable wax cylinders and are quite old, the importance of transferring them to a permanent base at this time is apparent. In prosecuting this work the National Archives will perpetuate and vitalize for posterity evidence of a significant culture rapidly fading from the American scene. Many songs in the collection are unique because their singers have died and the younger generation of the tribes does not know the beauty and wisdom of their ancestral ceremonies. In a few years it will be too late to save the creative work of the first Americans.

The titles of the songs in this collection illustrate the colorful aspects of Indian music, such as "A Song of Thanks for Food," "Song When a Pony is Given Away," and "Feasting the Scalps." Some of the Indian singers listed are Holding Eagle, Wounded Face, Old Dog, Wolf Chest, Bill Thunder and John Bearskin.



STORAGE EQUIPMENT
FOR DISC COPIES OF THE COLLECTION OF AMERICAN INDIAN SOUND RECORDINGS.

The transfer of these records to a permanent base will make them available to students of music, ethnology and anthropology, and to all others interested in the culture of the American Indian.

T. P.

ART ALCOVE IN THE INDEX EXHIBIT OF THE SMITHSONIAN INSTITUTION

Although in the past year with the opening of the new National Gallery of Art the Smithsonian Institution has become a great art center, the field of art is modestly illustrated by one of the smaller alcoves in the Smithsonian Index Exhibit. Above and in the center wall is the leading caption—Art: Man's Esthetic Expression. Beneath this is a small round diorama showing prehistoric man painting pictures of animals on the walls of a cave in southern Spain, while a larger watercolor reproduction of one of the animals supplements and more clearly illustrates the theme of the group. These are flanked by two vertical sunken cases, one of decorated weapons and the other of textiles. These two cases serve to show that the urge to decorate has been applied to all of man's objects and materials, back to the earliest remains of human handiwork. The underlying statement for this wall is appropriately "The Urge for Art Expression is One of Man's Oldest Attributes."

The two larger side walls are devoted respectively to "Art and Man's Habitation," and "The Graphic Arts," the former having to do with decoration of man's structures, private and communal,

ART ALCOVE OF THE SMITHSONIAN INSTITUTION INDEX EXHIBIT

IN THE LEFT PANEL ARE EXAMPLES OF THE GRAPHIC ARTS—ETCHING, WOOD CUT, ENGRAVING, ILLUMINATED MANUSCRIPT, LITHOGRAPH, PHOTOMECHANICAL REPRODUCTION AND CHROMO LITHOGRAPH. IN THE CENTER PANEL ARE EXAMPLES OF PREHISTORIC, GRECIAN, MOHAMMEDAN AND OTHER ANCIENT KINDS OF ART. IN THE RIGHT PANEL ARE EXAMPLES OF PAINTING, SCULPTURE AND WEAVING.

CAVE DECORATION

A SECTION OF THE MODEL SET IN THE CENTER PANEL SHOWING PREHISTORIC MAN AT WORK.

the latter with decoration of messages and means of disseminating art by reproduction methods. In the former are shown, by specimens chosen not for their peculiar intrinsic importance but merely as illustrative types of their respective fields, the arts of painting, of sculpture, and of weaving. The art of architecture had to be omitted for reasons of space. On the opposite wall the development of the graphic arts is centered around an illuminated manuscript (in this instance a papal bull of the early Renaissance) flanked by examples of the main methods of engraving, lithography, etching and color reproduction. Such purely mechanical methods as photography are not included, although the Institution has large collections of such material and is fully aware of the growing place of art in manipulating photographic techniques. HERBERT FRIEDMANN

THE SCIENTIFIC MONTHLY

AUGUST, 1942

EVOLUTION OF THE LAND PLANTS

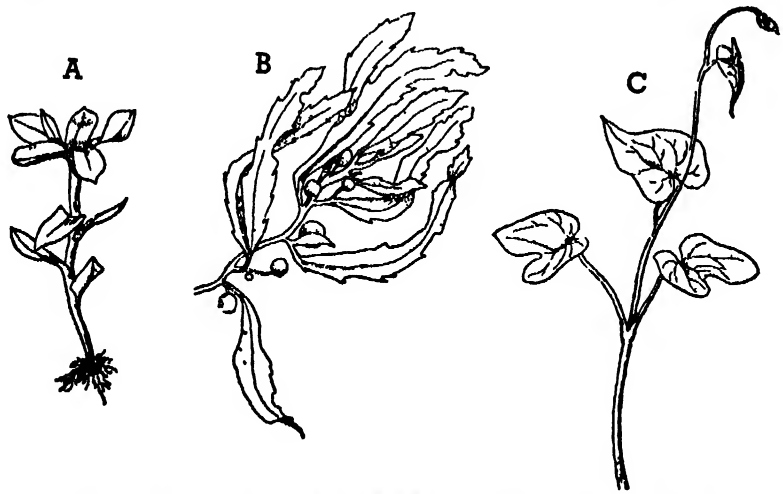
By Dr. D. H. CAMPBELL

PROFESSOR OF BOTANY, STANFORD UNIVERSITY

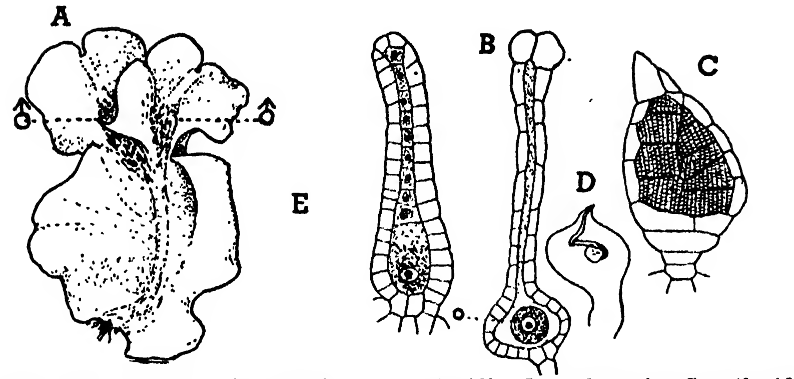
PLANT structures are much more uniform than those of animals, and it is hardly possible to establish such definite major divisions as are recognized in the Animal Kingdom. Where specialized tissues like the woody, skeletal structures of the higher plants are found, they are much less constant than those of animals, so that they are less reliable indicators of genetic relationship. The higher plants are also much less individualized than are most animals. An oak, for example, is a colony of potential independent plants rather than a true individual.

The higher plants, on the whole, are more conservative than are the higher animals. Thus many existing genera of flowering plants, *e.g.*, sassafras, poplar, are represented by fossil species at a period when the modern families of birds and mammals had not come into existence.

In seeking relationships among any groups of organisms it is in the simpler members of the groups that the resemblances are most evident. The highly specialized forms are usually the ends of definite phyla. Primitive characters, however, may persist in some of the most successful living types. Thus the anthers of the flowering plants are structurally much like the sporangia of some of the primitive ferns, and the development of the pollen grains (spores) is in no way essentially different from the spore-division of the simplest liverwort.



Homoplasy. A, leaves of a moss, *Mnium;* B, a sea weed, *Sargassum;* C, a seed-plant, morning-glory.



A, Gametophyte of a Liverwort, *Calycularia.* ♂, antheridia; B, archegonia; C, antheridium, of *Riccia;* D, spermatozoid of *Riccia.*

A comparison of the structure and development of the organs of plants may furnish a clue to the degree of relationship. Where the corresponding organs in the plants are shown to be genetically related, the organs are "homologous." Similar organs, *e.g.*, leaves, may occur in totally unrelated forms, such as algae, mosses and flowering plants. These similar but independently developed organs have been called "homoplastic."

All plants below the mosses (Bryophytes) are still treated in some current text-books as members of a single primary division, or sub-kingdom, Thallophyta. Within the Thallophyta are included plants ranging from microscopic bacteria and unicellular algae to massive fungi and giant sea-weeds of very complex structure. The inclusion in a single sub-kingdom of such a heterogeneous assemblage of obviously unrelated types is certainly far from scientific. While the term thallophyte might be retained for convenience, as zoologists use the term "invertebrates," in neither case should these imply a natural assemblage.

On the other hand, the three primary groups of green land plants, *viz.*, Bryophytes (mosses), Pteridophytes (ferns) and Spermatophytes (seed plants), often considered as sub-kingdoms, all agree in their essential reproductive structures. There is ample reason for uniting these three groups into a single sub-kingdom, Embryophyta, as proposed by Engler in his synopsis of the families of plants.

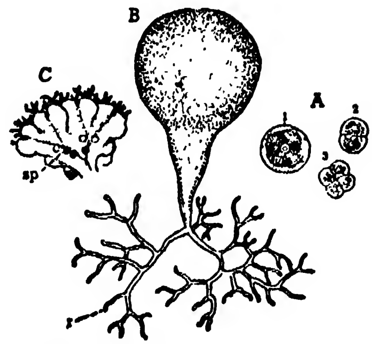
The usual division of the Embryophytes into Bryophytes, Pteridophytes and Spermatophytes is a somewhat artificial one, and the interrelationships of the principal classes and orders are by no means completely understood.

The life-cycle of all embryophytes shows two marked phases, sexual and non-sexual. This "alternation of generations" is most conspicuous in the lower members, the mosses and ferns. The sexual plant (gametophyte) bears the sexual organs, archegonium and antheridium, which contain the sex cells (gametes), the eggs and sperms. The archegonium in the liverworts and mosses is a flask-shaped structure, the neck consisting of usually 5 to 6 outer rows of cells, and an axial row whose lowest cell is the egg which occupies the base or "venter" of the archegonium.

The antheridium is less uniform than the archegonium. It may be a capsule, having a single layer of wall cells, enclosing a mass of "spermatocytes," each containing a bi-ciliate spermatozoid. The least specialized types are found in the lower pteridophytes. The greater part of the spermatozoid is composed of the nucleus of the spermatocyte.

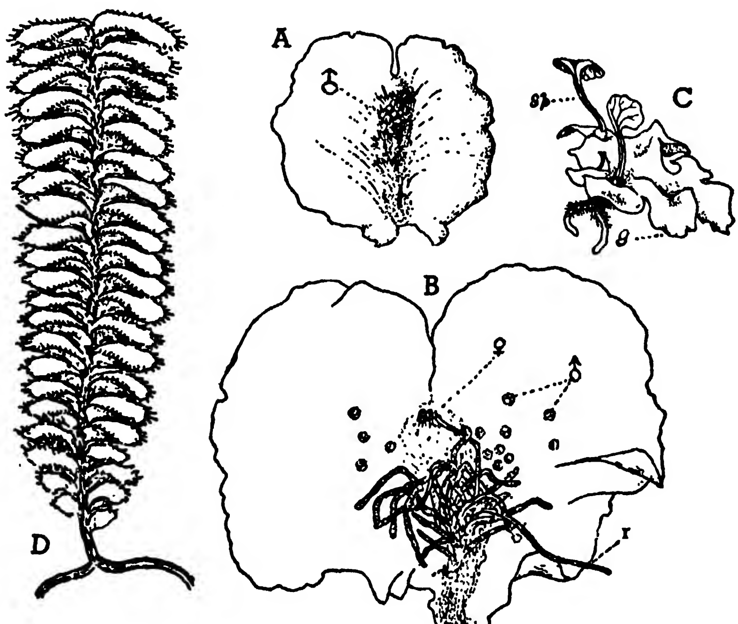
That the embryophytes are descended from aquatic ancestors is generally admitted. Of the Algae, certain fresh-water green algae most nearly resemble the lower embryophytes.

How and when the algal ancestors of the embryophytes took to the land is of course purely conjectural. The change from the aquatic habitat to life on land was presumably a very gradual one. There are still some very simple green algae which are adapted to terrestrial life, such as the unicellular *Protococcus* which vegetates so long as the atmosphere is sufficiently moist, becoming dormant when moisture is lacking. More striking is the curious little alga *Botrydium,* which grows on damp soil and is provided with a relatively extensive root system which enables it to absorb water for a relatively long time.

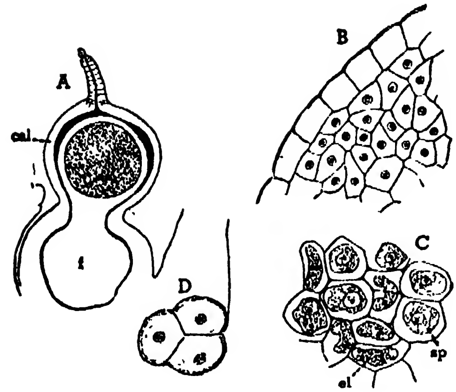


A, Unicellular Terrestrial Alga *Protococcus;* B, botrydium, a terrestrial alga showing branched roots, r; C, an amphibious liverwort, *Riccia natans;* sp. sporophytes.

The translation to land involves a complete readjustment of the plant to its water relation. The exposed surfaces must be protected against excessive evaporation, and this of course implies a diminution of power to absorb water from outside, and water is obtained, mainly, through a root system. The need for rapid distribution of water through the plant is met by the development of an elaborate "fibro-vascular" system of conducting tissues in the higher plants.

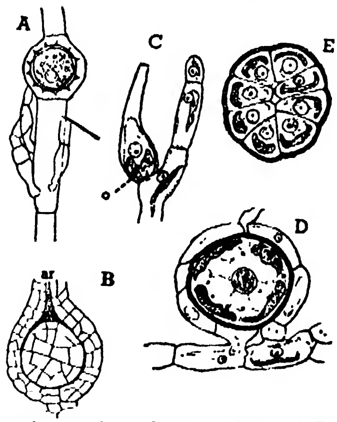


A, Thallose Gametophyte of a Liverwort, *Calycularia.* B, gametophyte of a fern *Gleichenia,* ventral view showing antheridia ♂, archegonia, ♀, r. rhizoids; C, gametophyte, g. of a fern, *Danæa,* bearing two young sporophytes; D, gametophyte of a leafy liverwort, *Plagiochila.*



A, Young Sporophyte of a Liverwort, *Targionia*, enclosed in the calyptra, cal., and the foot, B, section of the capsule, showing the young sporogenous tissue; C, an older stage, showing segregation of the spore-mother-cells and the elaters; D, young spore tetrad of *Fossombronia*.

The uniform conditions of the environment have tended to great conservatism in many fresh-water organisms, like some of the simpler green algae and protozoa which probably have come down little altered from the remotest antiquity. Once established on land, however, the environment is immensely more varied and the scope for the evolution of new forms correspondingly increased.



A, Oögonium of a Green Alga, *Œdogonium*, containing a ripe resting spore (zygote); B, archegonium of *Riccia* containing the multicellular embryo; C, oögonium of *Coleochaete*, o. the egg; D, ripe zygote of *Coleochaete* showing great increase in size; E, germinating zygote. (C–E after Oltmanns.)

The gametophyte may be of relatively large size in some of the liverworts and mosses; but in some of the pteridophytes and flowering plants it becomes greatly reduced in size, and finally in the flowering plants is of microscopic dimensions and generally overlooked.

The ciliated spermatozoids resemble those of some of the green algae and like them need free water in order to function. When wet, the antheridium discharges the spermatozoids which swim to the archegonium, which opens and permits their entrance. The necessity of free water for effecting fertilization indicates that the gametophyte has developed from some aquatic algal ancestors. The fertilized egg is called the "zygote." In the green algae the zygote usually develops a thick wall and becomes a "resting spore," which survives periods of drought, and may be said to be the terrestrial phase of the plant. When it germinates, it produces free swimming spores, from which the new generation arises.

The spermatozoid penetrates the egg-cell and the chromosomes of the two gametes are mingled in the nucleus of the "zygote" formed from this union, which has thus twice the number of chromosomes of the "haploid" nuclei of the gametophyte and is "diploid." The fertilized egg (zygote) increases in size and undergoes repeated divisions and forms the multicellular "embryo," all of whose cells have diploid nuclei.

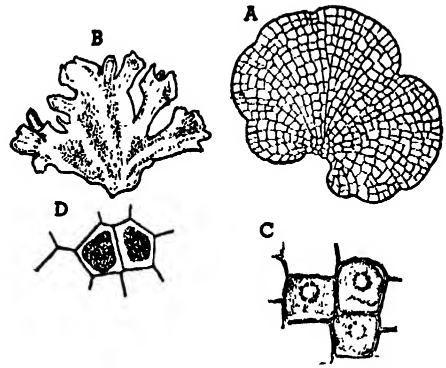
The embryo finally develops into the more or less complex structure, the "sporophyte," which sooner or later produces certain cells which divide into tetrads of "spores." The first division in the spore mother-cell is a "reduction division" or "meiosis," and the spores have the haploid chromosome number. Spore formation is a non-sexual process and the sporophyte is strictly an asexual or neutral organism. The spores on germination produce the haploid gametophytes.

Assuming the embryophytes have been derived from some algal ancestors, and that the sporophyte is an elaboration of the unicellular zygote, or resting spore of an alga resulting from the union of the gametes, we may say that the sporophyte of the embryophytes, like the algal zygote, represents the terrestrial phase of the organism contrasted with the aquatic or amphibious gametophyte. As the terrestrial habit becomes more pronounced the sporophyte assumes increasing importance until finally it becomes the dominant phase in the life-cycle.

The gametophyte reaches its highest degree of specialization in some of the large true mosses. These develop relatively large leafy shoots, which show special mechanical and conducting tissues, which might be compared to those in the fern-sporophyte. The roots, however, never reach the complex structure found in the ferns and seed-plants, and the mosses depend only to a limited extent upon their hair-like roots for their water supply, but absorb water directly through the leaves, thus behaving like algae.

The apparent inability of the gametophyte to develop adequate roots probably accounts for its failure to reach dimensions at all comparable with the sporophytes of many of the higher plants. So far as known the higher mosses represent the extreme development on land of these originally aquatic organisms, which seem unable to produce a plant type perfectly adapted to life on the land.

The further evolution of the plant kingdom is concerned mainly with the neutral generation — the sporophyte. This may be traced back to the "zygote" or resting spore, developed in many green algae, as the last phase in their life-history. The zygote may be said to represent the terrestrial phase of the alga, as it is fitted to survive drought,

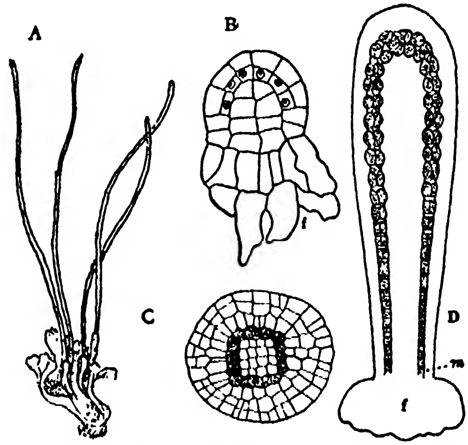


A, *Coleochaete scutata* a green alga; B, gametophyte of *Notothylas* (anthocerotaceæ); C, chromatophores of *Coleochaete;* D, chromatophores of *Megaceros* (anthocerotaceæ).

and carry the plant over from one growing period to another.

The sporophyte is, therefore essentially a terrestrial organism.

While there is a wide gap between the zygote of any known alga and the simplest sporophyte among the liverworts, nevertheless a comparison of the two may help to explain the origin of the sporophyte in the archegoniates.



A, Gametophyte of Anthoceros bearing four sporophytes; B, embryo of *Anthoceros*, longitudinal section, the nuclei are shown in the cells of the primary sporogenous tissue, the archesporium; C, cross section of an older embryo, the archesporium shaded; D, diagram showing the development of the sporogenous tissue from the basal meristem, m; f. the foot.

In the green alga, *Coleochaete,* there is a marked increase in size of the zygote after fertilization, and the formation of a globular cell-mass on germination, which suggests the early divisions in the simplest known sporophyte of the embryophytes — that of the liverwort, *Riccia,* where the fertilized ovum forms a globular mass of cells, the embryo, all of whose cells, except the single superficial layer, are spore mother cells. It is probable that in the first embryophytes all the cells are sporogenous.

The further evolution of the sporophyte is associated with an increasing subordination of the sporogenous or "fertile" tissue to sterile vegetative tissues. This "sterilization" of potentially sporogenous cells, as the most important factor in the evolution of the sporophyte, has been especially emphasized by Professor F. O. Bower. The theory of progressive sterilization explains the increasing importance of the sporophyte in the history of the land plants.

In most of the liverworts (Hepaticae) there is an early division of the embryo into an upper (epibasal) sporogenous region and a lower (hypobasal) sterile region. The latter develops a "foot" or haustorium, through which the embryo receives nourishment from the gametophyte, upon which the young sporophyte is thus parasitic. The epibasal region develops a capsule, whose inner tissue is composed, at least in part, of potentially sporogenous cells. Some of these become spore mother cells and produce the characteristic spore tetrads.

In the Hepaticae the sporophyte, except in its early stages, has little green tissue, and must, therefore, depend largely upon the gametophyte for its food supply, the whole development of the sporophyte (sporogonium) being mainly devoted to the production and dispersal of the spores. After the spores are shed there is a complete collapse of the sporogonium.

In the other classes of the bryophytes the mosses (Musci) and the Anthocerotes, there is a marked reduction in the sporogenous tissue, and the development of a considerable amount of green tissue which permits photosynthesis, and thereby enables the sporophyte to manufacture part, at least, of its necessary food; and except for its water supply, renders the sporophyte, to some extent, independent of the gametophyte.

The first group of embryophytes—the bryophytes includes three classes, Anthocerotes, Hepaticae (liverworts) and true mosses (Musci). So far as known, these all agree in having minute bi-ciliate spermatozoids, resembling those of some green algae (Chlorophyceae). The order Ulothricales, both in cell structure, and to some extent in reproduction, approaches most nearly to the lower embryophytes. The gametophyte of the latter may be a quite undifferentiated flat thallus, composed of uniform cells, each with a single chromatophore, very much like that of the Ulothricales. In all the bryophytes and pteridophytes there is a definite archegonium developed, and these two groups are often called the Archegoniates.

The relationships of the three classes of the bryophytes are by no means clear. The Anthocerotes are very generally placed with the Hepaticae—but they differ so markedly from the other bryophytes as to warrant their separation as a distinct class.

The Anthocerotes form a very natural class, with no very evident relationship with the other bryophytes. While the gametophyte is perhaps the most primitive among the Archegoniates, the sporophyte is much better developed than in any of the Hepaticae.

In the genus *Anthoceros,* the conditions approach those of the simplest vascular plants.[1] At an early period there is formed between the foot and the

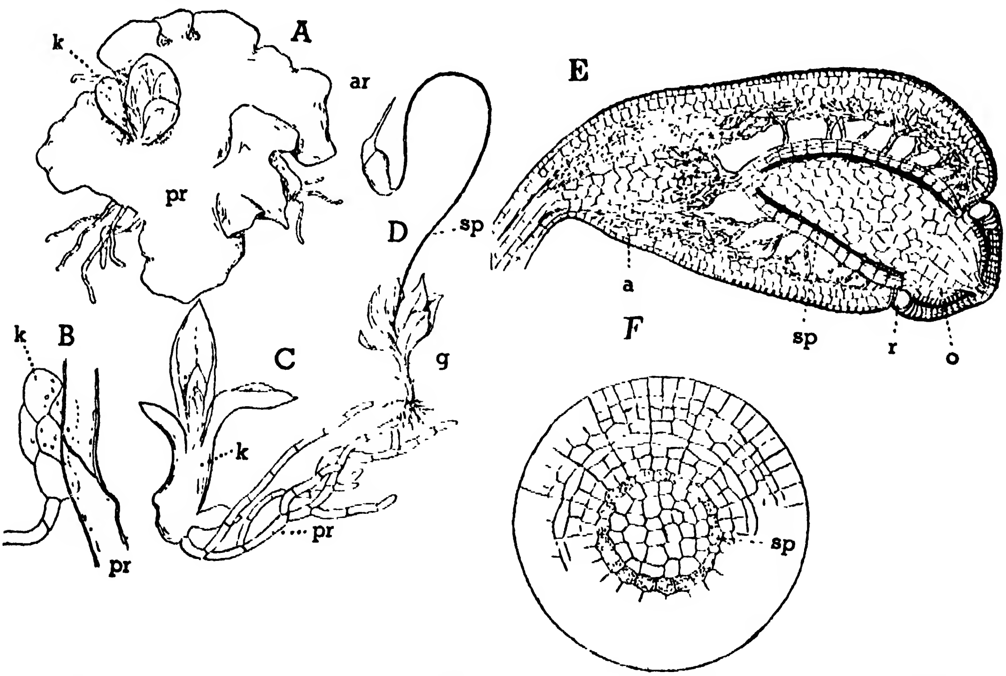
[1] Pteridophytes, Spermatophytes.

sporogenous region of the embryo a zone of rapidly growing cells (meristem), which may retain its activity for several months, and the apical region is thus pushed up and rapid elongation results, the sporophyte sometimes reaching a length of 10 centimeters or more. The sporogenous tissue (archesporium) consists of a single layer of cells enclosing an axial cylinder, the "columella," which sometimes, at least, seems to be an efficient conductor of water, absorbed by the large foot. Outside the sporogenous layer are several layers of green cells, and an epidermis with stomata like those of the higher plants. There is thus an efficient photosynthetic apparatus, and the structure of the sporophyte suggests that of the simplest so-called vascular plants.

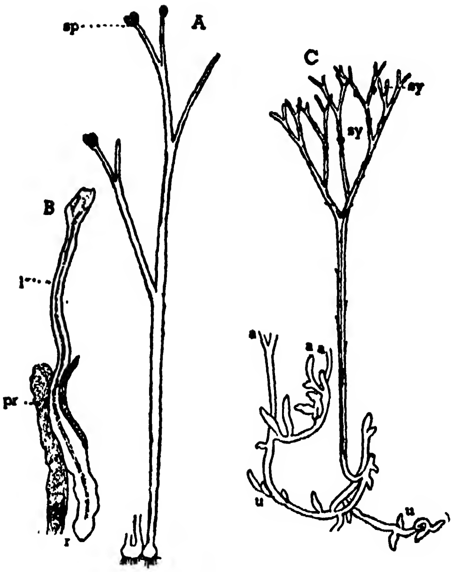
In the Hepaticae, the gametophyte may be an undifferentiated thallus comparable to that of *Anthoceros* but there is a considerable range of structure within the class. Thus in the genus *Pallavicinia,* as well as some others, the gametophyte has a distinct midrib which may have a central strand of conducting cells—suggesting the fibro-vascular bundles of the higher plants. In other genera there is the development of marginal lobes which may assume a definite leaf-like form. These "leaves" have evidently been developed independently in several unrelated families.

In other cases, the thallose form of the lower liverworts is retained but there is a notable differentiation of the tissues. In these there is a very definite epidermis and a system of air chambers containing chlorophyllous cells and communicating with the exterior by means of special pores in the epidermis.

In the true mosses (Musci) the gametophyte in most cases consists of a system of branching alga-like filaments, the



Mosses (Musci). A, thallose protonema of a peat-moss, *Sphagnum;* B, protonema of *Funaria,* with young leafy shoot, k; C, branching protonema of *Funaria,* with young leafy shoot; D, leafy shoot of *Funaria,* with mature sporophyte, sp.; E, longitudinal section of nearly mature capsule of *Funaria;* F, cross-section of young capsule of *Funaria,* sp. the archesporium.



A, *Hornea,* one of the earliest known vascular plants, restoration by Kidston and Lang; sp. sporangia; B, *Ophioglossum,* a primitive fern, section of young sporophyte showing only the first leaf, and primary root pr. gametophyte; C, *Psilotum,* probably the nearest living relative of the fossil *Homea.*

"protonema," from which the leafy shoots arise. These leafy shoots may reach considerable size, and the stem may have a well-developed conducting strand comparable with the vascular bundles of the higher plants. The leaves also are sometimes relatively large, and generally have a conspicuous midrib. These large mosses represent the most perfect development achieved by the gametophyte of the embryophytes.

If we regard the gametophyte of *Anthoceros* as the most primitive among the embryophytes, it may be that the other bryophytes, the Hepaticae and Musci, perhaps represent two divergent lines arising from some *Anthoceros*-like common stock.

Pteridophytes

In the pteridophytes the sporophyte becomes an independent plant, developing definite organs, leaves, roots and special spore-producing organs, sporangia. At an early period, in most cases, the primary root ruptures the gametophyte and penetrates the substratum and the plant thus becomes entirely independent. The sporophyte may ultimately attain a large size and live for many years.

The history of the sporangial structures shown by the fossil record as well as by the comparative anatomy of the more primitive living types makes it pretty clear that the sporangia are not primarily modifications of stem and leaf structures, but are primary organs. While in many of the more specialized ferns the sporangia arise from superficial cells of the leaf, in the more primitive types before the plant body was differentiated into stem and leaves, definite sporangia are present, and the sporangium must be considered as a primary organ of the sporophyte and not as a secondary one. The sporangia are often borne on special structures, sporangiophores.

The pteridophytes and spermatophytes always have a very definite system of conducting tissue, the "fibro-vascular" bundles, hence they are often called the "vascular" plants.

The simplest known vascular plants are two fossil genera, *Rhynia* and *Hornea,* first described by Kidston and Lang[2] from the Lower Devonian of Scotland. They were slender leafless plants sometimes scarcely exceeding in size the sporophytes of some species of *Anthoceros.* Some of the branches bore simple sporangia which show some resemblance to the spore arrangement in the *Anthocerotes.*

The section of the shoot also resembles a similar section of certain large sporophytes of *Anthoceros;* and so marked are the resemblances between these ancient pteridophytes and the sporophyte of *Anthoceros* that it seems possible the

[2] R. Kidston and W. H. Lang, *Trans. Roy. Soc. Edinb.,* 1–5, 1917–1921.

Rhyniaceae were derived either from some of the *Anthocerotes* or from forms resembling them.

Perhaps related to the Rhyniaceae are several more highly specialized Devonian types which it has been suggested might be the prototypes of the living pteridophytes. Of the latter the ferns (Filicineae) are characterized by the marked development of the leaves; in the horsetails (Equisetaceae) and the club-mosses (Lycopodiaceae) the axis is predominant and the leaves relatively secondary.

Classification of Pteridophytes

The existing pteridophytes include four classes,—1. Psilotineae; 2. Filicineae (ferns); 3. Equisetineae (horse-tails); 4. Lycopodineae (club-mosses).

The Psilotineae are few in number, with only two genera, *Psilotum* and *Tmesipteris;* and are the nearest living relations of the Devonian Rhyniaceae. The commonest species is *Psilotum triquetrum,* occurring in tropical and subtropical regions of both hemispheres. It has a much-branched subterranean rhizome, from which upright dichotomously branched shoots arise. There are only rudimentary scale leaves and no roots, and there is a distinct superficial resemblance to *Rhynia.*

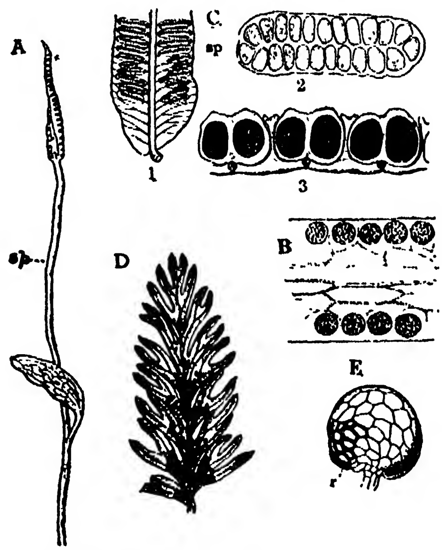
The spores in the Psilotaceae are formed on a short branch, or sporangiophore, and are in two (*Tmesipteris*) or three (*Psilotum*) separate masses forming a "synangium" instead of the individual sporangia found in most of the pteridophytes.

The gametophyte is a subterranean body, without chlorophyll. The spermatozoides are multiciliate.

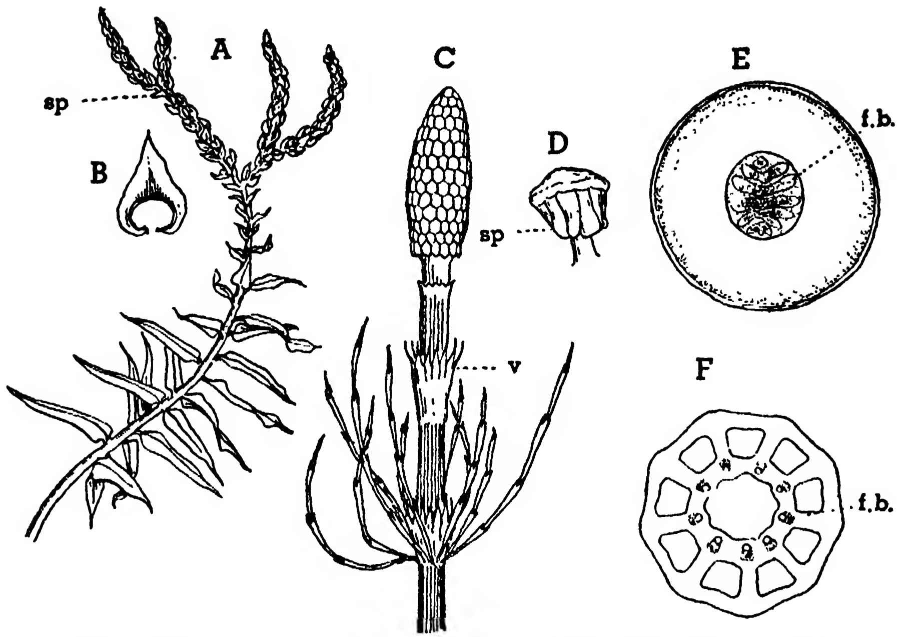
The three other classes can be traced back to the Palaeozoic, where many fossil forms occur. Whether these three classes have arisen from a common Devonian stock related to the Psilophyta is not clear, but fossils evidently related to all the existing classes occur in early Carboniferous rocks and probably in the Devonian.

At the present time the ferns greatly outnumber all the other pteridophytes and constitute the great majority of existing species.

The great majority of ferns belong to the section Leptosporangiatae, evidently a comparatively modern group. In these the sporangium is often developed from a single epidermal cell. The ferns are characterized by the predominance of the leaves, which in some of the tree-ferns reach a size and complexity which is rivaled by few of the higher plants. The more primitive ferns, the Eusporangiatae, have much larger and less specialized sporangia than those of the Leptosporangiatae. The Eusporangiatae are best developed in the tropical and subtropical regions. There are two orders, Ophioglossales and Marattiales, each



A, Ophioglossum *Moluccanum*, sp. the conspicuous sporangiophore; B, section of the sporangiophore of *O. pendulum*, showing the separate masses of spores; C, (1) lower surface of a leaflet of *Danæa*, showing the elongated synangia, (2) horizontal section of a synangium, (3) transverse section of three synangia; D, leaflet of *Leptopteris*, showing scattered free sporangia; E, a single sporangium of *Leptopteris;* r, annulus.



A, *Lycopodium pachystachyon.* B, single sporophyll; C, *Equisetum limosum;* v. leaf sheath; D, sporangiophore, and sporangia of *Equisetum;* E, section of stem of *Lycopodium dendroideum;* F, section of stem or *Equisetum arvense.* F.b.—fibro-vascular bundles.

with a single family. In the Ophioglossaceae the sporangia are borne on a large sporangiophore, which sometimes, at least, is formed by a forking of the very young leaf into a fertile sporangiophore and sterile lamina. In *Ophioglossum* the sporangiophore is a flattened spike, the sporangia forming a single row on each margin. Each sporangium consists of a large mass of sporogenous tissue, opening by a cleft on the surface of the sporangiophore.

The Marattiales have the sporangia borne on the lower surface of the leaves, as in the common ferns, but in most cases the sporangia are not free but are united into a "synangium."

The gametophyte of the ferns usually resembles that of the more primitive Hepaticae. In the Marattiaceae the large fleshy thallus might readily be mistaken for a liverwort.

In most of the ferns the sporangia are all alike and the spores produce gametophytes which often bear both antheridia and archegonia. There are, however, a few ferns, the Hydropterides or water ferns, in which two types of sporangia are produced. These are of different size, the larger megasporangium, having a single very large spore, the megaspore, from which the female gametophyte is developed. The smaller microsporangia produce many "microspores" which give rise to the greatly reduced male gametophytes.[3] Heterospory has developed in several quite unrelated families.

The Embryo

In the lower ferns, the first division of the embryo is transverse and the basal walls separate a lower foot region from the upper region from which the leaf

[3] The development of these two types of spores is known as "heterospory," and this has arisen in several unrelated groups of pteridophytes. Where all the spores are alike the plants are "homosporous."

and stem develop. The young embryo, therefore, may be described as bipolar. The embryo at this stage may be compared with that of *Anthoceros.* The embryo may reach a considerable size before the organs of the young sporophyte are recognizable and perhaps those forms in which early differentiation occurs are the more recent and specialized.

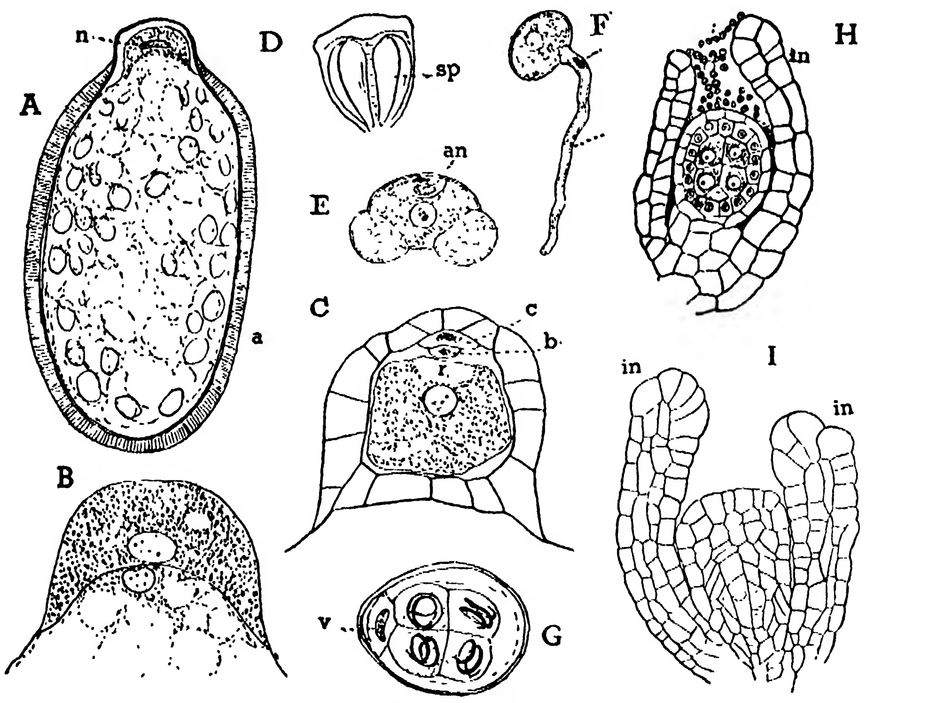
The leaf soon assumes the leading role in the development of the young sporophyte and the stem may be completely suppressed in the young stages of some species of *Ophioglossum,* a genus which for several reasons may be regarded as the most primitive of existing ferns.

Equisetineae

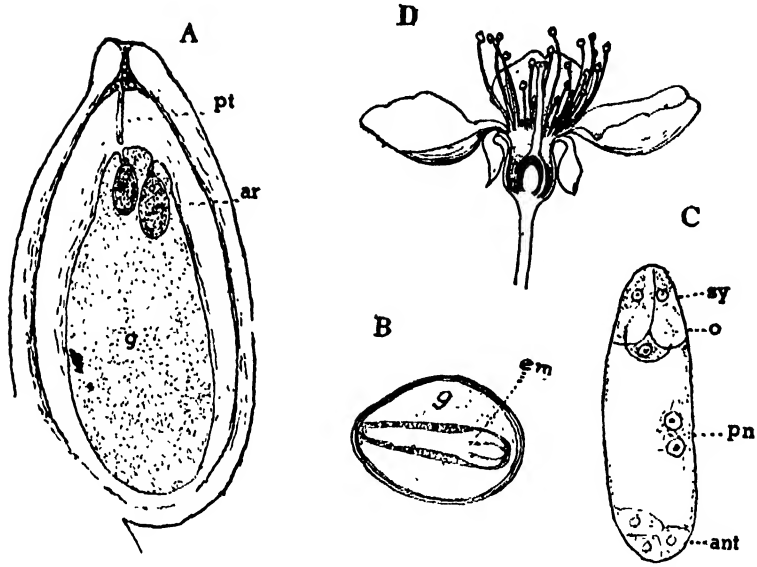
The Equisetineae have only a single living genus, *Equisetum.* The hollow-jointed stem and rudimentary leaves show little resemblance to any of the ferns, but the large green gametophyte is not very different and the sex organs are similar. The large multiciliate spermatozoids closely resemble those of the lower ferns and the embryos have some points in common. Some of the fossil Equisetineae had functional leaves, and it is possible that a real, if very remote, relationship may exist between the Equisetineae and Filicineae.

Lycopodineae (Club Mosses)

The Lycopodineae have little in common with the other pteridophytes and probably had an entirely separate origin. They include both homosporous and heterosporous forms. The gametophytes



Heterospory. A, section of megaspore of *Marsilea;* n, nucleus. B. C, development of the female gametophyte and archegonium of *Marsilea;* D, scale from the staminate cone of a pine, showing two microsporangia (pollen-sacs); E, pollen-spore of a pine, the enclosed male gametophyte shows the antheridial cell, An.; F, germinating pollen-spore of sweetpea; G, microspore of *Isoetes,* enclosing the male gametophyte, v. prothallial cell, four spermatozoids; H, megasporangium of a water-fern, *Azolla;* I, young megasporangium (ovule) of redwood (*Sequoia*).



Seed Plants. A, mature ovule of a pine, showing the large female gametophyte, g. with two archegonia; a pollen-tube, pt, is penetrating the ovule; B, section of pine seed, g. the gametophyte (endosperm), em. the embryo; C, embryo sac of an angiosperm; at the apex the egg apparatus; o, the egg, sy. synergids; at base, three antipodals; p.n. polar nuclei; D, section of a cherry flower, an angiosperm showing the various organs.

of the homosporous forms (Lycopodiaceae) are mostly subterranean and destitute of chlorophyll, although some develop chlorophyll. The sexual organs, especially the archegonia, recall the mosses.

The leaves are small with a simple midrib, the whole sporophyte with the slender stem and numerous leaves suggesting some of the larger mosses, hence the common name, "club mosses." There are many fossil lycopods, some of them being trees, like the living conifers. Some of the fossils, however, are closely related to the living genera, *Lycopodium* and *Selaginella.* In some of the larger fossil forms, *e.g., Lepidodendron,* seeds were formed.

Heterospory and the Seed Habit

The occurrence of heterospory in several unrelated pteridophytes must be borne in mind in considering the origin of seeds, in both living and extinct plants. In the water ferns, Hydropterides, the ripe megaspore is unicellular and contains reserve food materials from which the developing gametophyte is nourished. In *Selaginella,* of the Lycopodineae, the development of the gametophyte begins long before the megaspore is full grown and it reaches its full development while the megaspore is still retained in the sporangium. The conditions are very much like those in the lower seed plants, the so-called "gymnosperms." In the seed plants the megasporangium is known as the "nucellus" of the ovule, or young seed. Thus the development of the gametophyte within the megaspore (embryo-sac), in a pine, for example, is very much like that in *Selaginella.*

The microspores (pollen-spores) of the seed plants differ but little from those of the pteridophytes. The megaspore with the contained gametophyte remains within the ovule and the archegonium is fertilized by means of the male gametes formed in the rudimentary

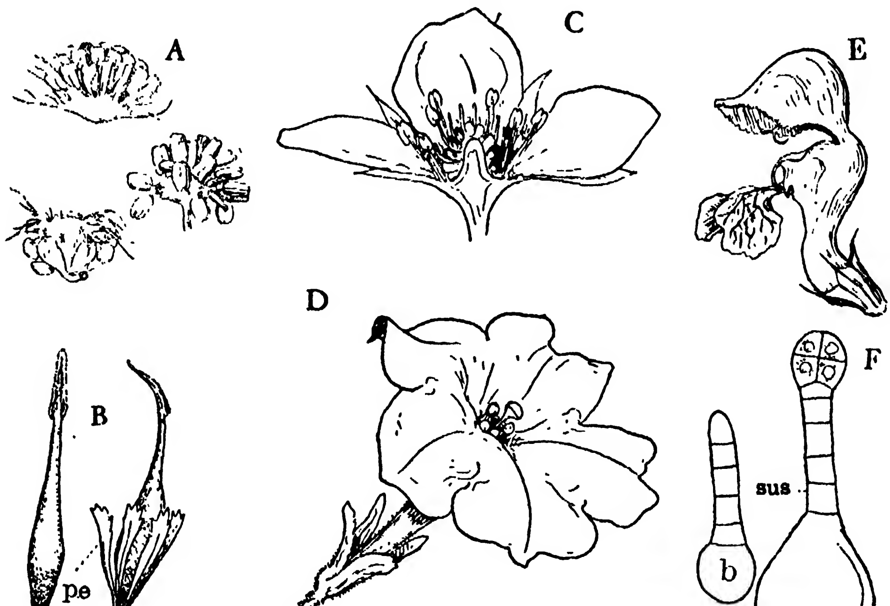
male gametophyte developed from the pollen-spore which is deposited on the apex of the ovule. The pollen-spore germinates and forms a tube which penetrates the apex of the nucellus and reaches the archegonium. With few exceptions the male gametes are not ciliated and free water is no longer essential for fertilization of the egg. After fertilization the outer tissues of the ovule become hard, forming the seed-coat, and the cells of the gametophyte, in which the embryo is embedded, are filled with reserve food. This gametophytic tissue is the "endosperm" of the ripe seed.

That like heterospory seeds have developed independently in several phyla is shown clearly by a study of the Palaeozoic floras. While some of the ancient seed plants show a relationship with existing types others are apparently quite unrelated to any living plants.

Among the most abundant of the Palaeozoic seed plants were the "Pteridosperms," usually with fern-like foliage, but bearing simple seeds. The oldest pteridosperms are found in the late Devonian. Other Palaeozoic seed plants were related to the Lycopods. No examples are known of seed formation in the Equisetineae.

Since it is clear that the seed habit has originated independently in various groups of pteridophytes, it is practically certain that the living seed plants are not all descended from a single primitive stock.

The primitive seed plants are "gymnosperms," *i.e.*, the ovules are not borne in a closed ovary. They show evident derivation from pteridophytic ancestors,



Types of Angiospermous Flowers. A, staminate flowers of poplar; B, pistillate flowers of *Sparganium simplex;* C, apocarpous flower of strawberry; D, (radial) actinomorphic sympetalous flower of *Petunia;* E, (bilateral) zygomorphic sympetalous flower of dead-nettle (*Lamium*); F, young embryos of shepherd's purse; sus. suspensor.

although not certainly related among themselves. The ancestry of the predominant flowering plants, the angiosperms, is very obscure, and is still the subject of much controversy.

The existing gymnosperms include four orders, Cycadales, Ginkgoales, Coniferales and Gnetales. The first two are very natural groups, but the others show much greater diversity, and their interrelationships are not very clear. The Cycadales and Ginkgoales show pretty clearly that they are related to the ferns. In one respect they differ from all the other living seed plants. The male gametes are large multiciliate sperms, recalling those of the lower ferns.

The cycads include about 85 living species which have fern-like leaves and resemble in many respects the structures of the eusporangiate ferns.

The Ginkgoales are represented by a single living species, *Ginkgo biloba*, sometimes cultivated in America. The leaves resemble in their venation the leaflets of some ferns. *Ginkgo* is not known in a wild state, but fossil remains of Ginkgoales are wide-spread from the early Mesozoic onward and are very much like the living species.

Abundant remains of foliage and stems of cycadean type are found from the late Palaeozoic through the Mesozoic. Many of these have been found to belong to another order of cycadophytes—Bennettitales—now quite extinct. They had much more specialized flowers than the true cycads, and it has been thought by some botanists that the Bennettitales were the ancestors of the flowering plants, but this is very doubtful.

Coniferales

The existing cycads and *Ginkgo* are evidently relicts of a flora once much more extensive than at present. The Coniferales, although comprising only about four hundred living species, play a very important role in the vegetation of the modern world. Over extensive areas, like western North America and parts of Europe and Asia, they form the major elements in the forests. They are sometimes trees of gigantic size, like the redwoods, pines and firs of the Pacific Coast.

Gnetales

The order Gnetales has three genera which differ very much in appearance and are evidently not closely related. Only one genus, *Ephedra*, occurs in the United States. The other genera are mostly tropical.

From the Permian through the Mesozoic, gymnosperms were predominant. From the Lower Cretaceous onward they diminish in importance and are superseded by the angiosperms, Anthophyta ("flowering plants"), which at present form an overwhelming proportion of the vegetation everywhere. The angiosperms differ greatly from the gymnosperms in their adaptability to all conditions where plant-life is possible. They range from almost microscopic aquatics to giant trees, rivalling the largest conifers. At least 150,000 species of angiosperms have been described, while the total number of species of living gymnosperms is probably not more than 500.

In the angiosperms the ovules (young seeds) are borne in a special closed structure, the ovary, instead of being exposed like the ovules of the gymnosperms.

The flowers of the angiosperms show an extraordinary range of structure. The essential organs are the stamens and carpels, which are usually in the same flower, but may be separated. The stamen which might be regarded as a sporangiophore usually has a stalk (filament) bearing in most cases a synangium (anther) with four microsporangia (pollen-sacs). The development of the

anther is very much like that of the synangium of some of the lower ferns. The ovules (megasporangia) are borne at the base of the carpels, which may be separate or united into a "pistil." The base of the pistil is the ovary, above which is the cylindrical "style," bearing at its summit the stigma, upon which the pollen spores are deposited. The carpels are commonly considered to be "sporophylls," *i.e.*, modified leaves, but the foliar nature of the carpels is at least questionable.

In its simplest form the flower may consist of a single stamen or carpel, but more commonly both organs are present and in addition there is a more or less conspicuous envelope or perianth, with two series of leaf-like members, sepals and petals, forming the "calyx" and "corolla." The sepals are generally green and leaf-like, but the petals are usually delicate in texture and often showy. They probably represent modified stamens.

Many of the specialized characters found among the angiospermous flowers are obviously associated with pollination by insects, which have played a very important role in the evolution of the flowers; and there are very many examples of mutual adaptations between insects and flowers.

The geological history of the angiosperms is very incomplete. There is abundant evidence of the existence of certain living genera, *e.g.*, *Sassafras, Platanus,* in the Lower Cretaceous, and this implies a long line of more primitive types presumably extending into the Jurassic, but as yet the evidence is very uncertain.

The distinguished botanist, Engler, in the introduction to the angiosperms in the "Natürliche Pflanzenfamilien," assumes the existence, probably in the Jurassic, of an extensive and wide-spread assemblage of "Protangiosperms," from which many independent lines of true angiosperms arose. However, as yet none of these protangiosperms have been definitely recognized.

In the absence of satisfactory fossil data, the problem of the origin of the angiosperms must, for the present, remain largely conjectural. It seems unlikely that they are directly related to any of the existing gymnospermous orders, and it has been suggested that they may have originated directly from some type related to the ferns, or possibly the pteridosperms.

MERIDA, VENEZUELA—FROM ISOLATION TO INTEGRATION[1]

By Dr. RAYMOND E. CRIST
DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF ILLINOIS

Swiftly moves the wind; swiftly moves the stream; swiftly moves the rock that falls from the mountain.
Run, warriors, run out against the enemy, run swiftly, like the wind, like the stream, like the rock that falls from the mountain.
Strong is the tree that resists the wind; strong is the rock that resists the river; strong is the mountain snow that resists the sun.
Fight, warriors, fight valiantly, show yourselves strong—like the trees, like the rocks, like the snows of our mountains.

—*War chant of the Indians of the Venezuelan Andes*

THE native Venezuelan poet made use of the imposing phenomena of the high mountains to symbolize the impetuous attack: the howling wind which, in the high passes, can even blow over horse and rider; the mountain torrent which sweeps all before it; the massive rock which breaks loose from a peak and flattens everything in its path. In the great tree that calmly resists the wind; in the huge rock that even the rushing stream can not dislodge; in the perpetual snows of the peaks which resist the tropical sun—in these phenomena the bard visualizes the defensive strength of those who fight for their native land.

In the short distance between the mountains of Mucuchíes, which inspired this American Homer, and Lagunillas del Urao—some fifty miles—almost any of the plants known in the world will thrive. It is not unusual for one hacendado to have within the limits of his hacienda fields of cacao and sugar-cane in the irrigated area along a river and patches of wheat and potatoes high up in the cold country. This short altitudinal traverse would represent a difference in latitude of a thousand miles or more—from the sugar-cane plantations of southern Louisiana to the wheat and potato fields of the valley of the Red River of the North.

One of the most characteristic geologic and topographic features of the Venezuelan Andes are the extensive terraces, the remains of vast alluvial flats which, during the Ice Age, were deposited by the overloaded streams coming from the melting glaciers, then much more extensive than now. The underloaded rivers of the post-glacial epoch, in cutting their beds to new base-levels, have eroded deep V-shaped valleys into the older alluvium, leaving extensive terraces or mesas high above their present level.

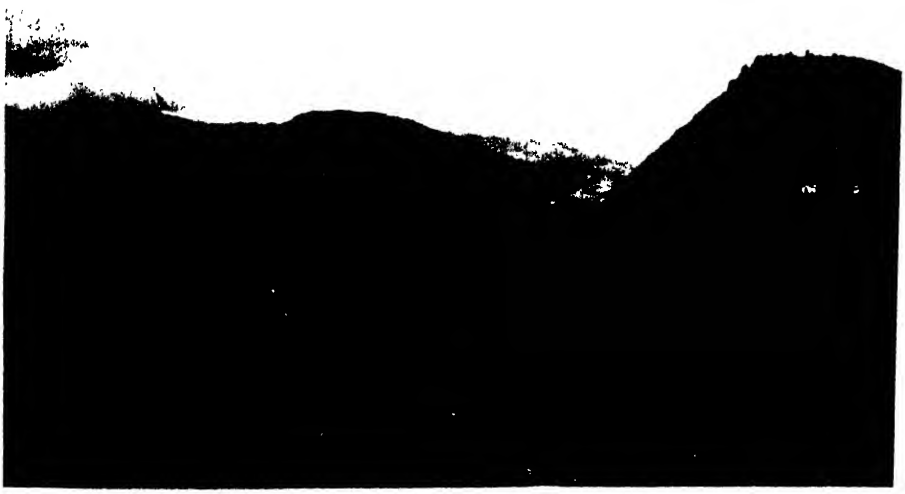
In the first days of June of 1558 Captain Juan Rodriguez Suarez set out northeastward from Pamplona with 100 men, in the search for new mines. He passed the sites where Cúcuta, San Cristóbal, La Grita and Bailadores are now located, and had many encounters with the Indians. At last he descended to the valley of the Chama at Estanques, and continued on up the arid valley past Lagunillas del Urao, where he found a dense population of peace-loving, industrious Indians. From Lagunillas eastward the country rapidly loses its desert aspect; streams become abundant, hills are wooded. The traveler is reminded now of New England, now of Brittany, now of the high Alpine meadows, depending on the time of year, the time of day or upon one's mood. At last, on October 9, 1558, Suarez reached the present site of Ejido, on a "high mesa, clean, with clear water, a beautiful view of the Sierra Nevada, and a temperate climate."[2] Where the Milla, Albarregas

[1] The work on this article was made possible by grants from the Guggenheim Foundation and the Graduate Research Board of the University of Illinois.

[2] Fray Pedro Simon, "Noticias Historiales de las Conquistas de Terre Firme," p. 196. Bogotá, 1882.

VILLAGE OF LAGUNILLAS AND THE LAKE

FROM WHOSE WATERS "TRONA" IS EXTRACTED. THIS MINERAL IS MIXED WITH A TOBACCO EXTRACT TO FORM A BLACK PASTE CALLED "CHIMÓ," WIDELY USED BY THE ANDINOS.



DEEP V-SHAPED VALLEY CUT BY THE MUCUJUN RIVER

THE ALLUVIAL FLATS WERE DEPOSITED BY THE OVERLOADED STREAMS OF THE ICE AGE.

and Mucujun rivers join the turbulent Chama, an especially well-developed and extensive alluvial flat has been incised by the rejuvenated streams, forming a vast mesa of rich older alluvium, which must have seemed a veritable Garden of Eden to the dusty, sunburned captain and his men. He immediately assigned parcels of land to his soldiers and named the city "Mérida," after Merida, in Extremadura, Spain, his native city.

The three classes of towns in Latin America, according to origin, are: I. Towns of Indians, located either where they were found by the Conquistadores, or on a site designated by them. Spaniards were not allowed to live in these towns, and the Indians governed themselves under the supervision of the colonial authorities. To these towns or communities the king granted certain lands called "Resguardos de Indigenas," which lands were worked communally until, under the Republic, they were surveyed and divided among the Indians. II. Those which, without official founding, from an agglomeration of houses (hamlet), grew into villages or even, if the positions were favorable, into full-fledged towns or cities. Generally towns of this kind developed on sites owned by private individuals, or on land donated for such a purpose by some rich benefactor. III. Those towns which were directly founded by Spaniards, as a Villa (town) or Ciudad (city). Many formalities had to be complied with for such a foundation, beginning with permission of the King, the Real Audiencia or the Governor of the Audiencia. The act of founding was carried out with much pomp, and one of the first acts after the imposing ceremony was the designation of the sites for the public plaza, the church and the town hall. The "Ejidos," or common lands, of the new town were laid out at the same time.

A PRIMITIVE "TRAPICHE" OR SUGAR MILL IN OPERATION
THE MOTIVE POWER IS SUPPLIED BY A YOUNG OX.

But to return to Captain Suarez. On October 14, 1558, he wrote a letter to the Cabildo of Pamplona in which he told of assigning lots to his soldiers in the new town, spoke of the lovely view of the

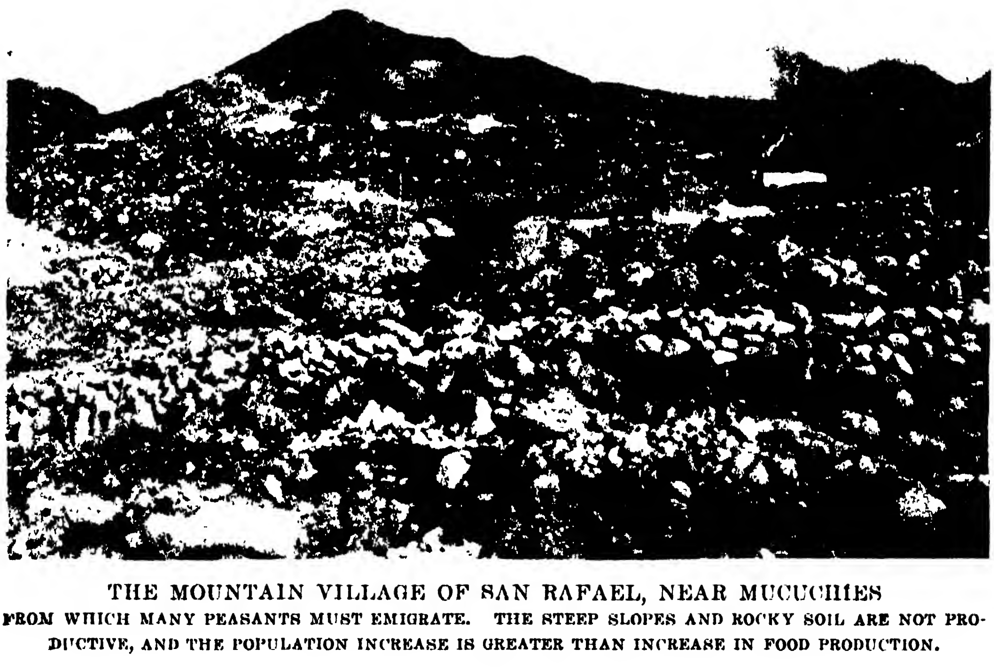
PANORAMA OF ALLUVIAL TERRACES DOWNSTREAM FROM EJIDO

DISSECTED IN THE FORM OF FLAT IRONS. ON BOTH THE OLDER ALLUVIAL FLAT AT THE HIGH LEVEL AND THE MORE RECENT ALLUVIAL TERRACE BELOW ARE IRRIGATED FIELDS OF SUGAR-CANE.

VERTICAL CLIFF OF OLDER ALLUVIUM AS SEEN FROM A CANE FIELD

A PILE OF "BAGASSE" DRYING IN THE SUN

THE BAGASSE, WHEN DRY, IS USED AS FUEL TO BOIL THE CANE JUICE TO A THICK SYRUP. THE SYRUP, WHICH LOOKS LIKE TAFFY CANDY, IS COOLED IN A HUGE WOODEN VAT AND POURED INTO MOLDS, WHERE IT HARDENS AND FORMS YELLOW SUGAR, "PANELA" OR "PAPELON," USED LOCALLY.



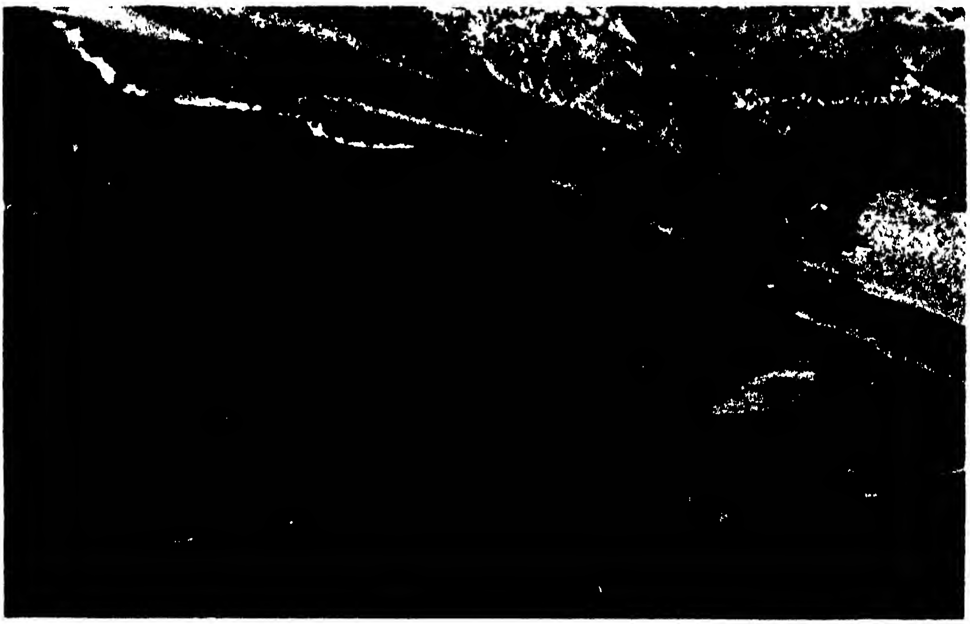
THE MOUNTAIN VILLAGE OF SAN RAFAEL, NEAR MUCUCHIES

FROM WHICH MANY PEASANTS MUST EMIGRATE. THE STEEP SLOPES AND ROCKY SOIL ARE NOT PRODUCTIVE, AND THE POPULATION INCREASE IS GREATER THAN INCREASE IN FOOD PRODUCTION.

Sierra Nevada, and mentioned the great number of people. He wrote that there were as many buildings as in Rome (straw huts, to be sure, as Fray Simon says), that he had found the best esteras (sleeping mats) that he had seen in the kingdom, and he requested that thirty or forty more soldiers be sent him, as they would be necessary in the pacification of so many people.

When Captain Juan Maldonado, son-in-law of Ortún Velasco, governor of Pamplona, heard of Suarez's activities, he became jealous and had the governor issue a warrant for his arrest, alleging actions outside his authority—particularly the founding of a town and the granting of land—and cruelties to the Indians. Maldonado then had himself appointed Governor of Mérida, which he moved from its former site, where Ejido now stands, to its present site, more as a protest against Suarez than for any other reason. After this he began explorations to the east, crossed the paramo to subdue the Timotes Indians, and finally reached the Boconó River. Here he met Captain Francisco Ruiz, who had been sent out to conquer these same provinces by the Gobernación of Venezuela. Thereupon he returned to Mérida and to the task of subduing the Indians.

The Caquetia and Jirajara Indians formed the dominant population around Mérida at the time of the conquest. They probably came originally from the Andes of Pasto, although it is hard to say why or when they left their native haunts to settle the Llanos and Andes of Venezuela. Perhaps the violent eruptions of the volcanoes of Pasto forced the people to seek new homes elsewhere, or perhaps the natural increase in population of these vigorous mountaineers made migration a necessity. Both tribes had entered the Venezuelan Andes from the



VALLEY OF UPPER CHAMA RIVER IN THE WHEAT COUNTRY AT MUCUCHIES

IN LEFT FOREGROUND THREE YOKES OF OXEN ARE BEING USED IN PLOUGHING A WHEAT FIELD WHICH IS BOUNDED ON TWO SIDES BY DEEPLY ERODED GULLIES. THE ALLUVIAL FAN ON THE OTHER SIDE OF THE RIVER IS INTENSIVELY CULTIVATED IN SMALL PLOTS FENCED IN BY STONE WALLS. THE CHAMA HAS BEEN PUSHED TO THIS SIDE OF THE VALLEY BY ALLUVIAL DEPOSITS OF ITS TRIBUTARY.

OXEN BEING UNHARNESSED FROM THEIR BURDENS AT THE KILN

south by the main river valleys, completely subjugating the highly developed sedentary population already there, which had probably immigrated originally from Central America. The words "muen" and "moco," meaning place or site, is found all along the upper Santo Domingo River and from the mountains of Aricagua to the Sierra Nevada, eloquent evidence of the recent conquest by the invading Quechua—Guarami people. Similarly, the names "berg" and "land" are found widely distributed over areas conquered by Teutonic peoples.

The Indians resisted the Spaniards bravely; they dug trenches to impede their progress, and they built stone fences to ward off their attacks. But lack of food and water finally forced most of them to surrender. Many were killed, others fled to the high mountains, and not a few buried themselves alive in "mintoys," subterranean dugouts with a narrow entrance that the fugitives closed after them. Here they died, idols clasped in their arms. Those who retired to the mountains kept up guerilla warfare for a generation, but were finally subdued.

The common method of pacification was that of giving "encomiendas," grants of land together with the Indians living on them, to Spaniards who were to indoctrinate the natives with Christianity. During this process, which often lasted centuries instead of only two generations as specified in the grant, the Indians worked on the estates as serfs. When the owner died the estate and the serfs passed on to his son or son-in-law. If there was no legitimate heir the estate returned to the Crown, and the King could then give it to some other worthy subject. For example, when Captain Gonzalo de Valencia died, leaving his encomiendas of Lagunillas and the valley of Santo Domingo without an heir, Captain Juan Velasquez de Velasco had the governor of Mérida grant, with royal consent, these encomiendas to Juan Felix Jimeno de Bohorquez, who was about to become his son-in-law. The Velasco and Bohorquez families, with great

wealth in land and serfs, played a leading role in the affairs of Mérida for generations.

Undoubtedly the terrible living conditions of the fugitive Indians in the mountains, as well as of those who were working on the encomiendas of the conquerors, helped make the smallpox plague of 1588 especially virulent. It was estimated that at least one third of the total population died. This appreciable loss in the native labor force in turn played an important role in the introduction of Negro slaves, particularly for the sugar, indigo and tobacco haciendas of Barinas, which traded with Spain via Mérida and Lake Maracaibo. But as early as 1619 the cacao haciendas along the Chama were worked by gangs of Negro slaves.[3]

One of the first acts in founding a town was the assignment of Ejidos, or common lands, as perpetual property of the municipality. But many were the subterfuges whereby such commons finally became the private property of individuals who often paid little or nothing into the city treasury.

The Ejidos of Mérida, with an interesting history for over 350 years, were originally very extensive, including all the mesa to the southeast as far as the present town of Ejido—hence the name —and to the northeast beyond La Milla. A part of the Ejidos was subdivided in 1564, but in 1587 the Real Audiencia of Bogotá, at the instance of Captain Antonio de Reinoso, cancelled certain concessions made shortly before. In 1589 Pablo Garcia, Procurador of Mérida, insisted that the Ejidos to the southeast be subdivided, alleging that Captain Reinoso had a very personal reason for not wanting the parceling to continue, *viz.:* that he wanted to continue using that part of the Ejidos as free pastureland for his cows. "Between the creek of Pablo Garcia and the Chama River . . . is an area ten kilometers wide, every bit of it common land and quite deserted, and no one is making use of it except the person who has his cows there, and he doesn't worry too much about them."[4] Furthermore, he alleged that Reinoso and his clique were interested in selling lots at high prices. On December 22, 1589, the Real Audiencia gave its permission to continue the subdivision, and in the week following concessions were made, but almost exclusively to the principal families, the members of the Cabildo, or city council, taking the choice locations. On December 29. 1589, the committee in charge of the division decided, after all, that smaller plots would be granted from then on. The entire council changed in January, 1590, and the subdivisions abruptly stopped.

The new Procurador, Miguel Baltazar de Vedoya, in a letter dated February 6, 1590, protested most energetically against the subdivisions made by the preceding council, which he accused of acting contrary to the decree of the Real Audiencia. This latter body, he felt, would not have approved the acts of the council:

> I plead and supplicate and, if necessary, although speaking with all deference, I require that your Honors declare null and void everything done by the preceding Cabildo prejudicial to the said commons, and that when these are divided with the permission and by the request of the Real Audiencia and Your Majesty, that there be levied each year and on each piece of land given an annual rent and perpetual tribute as income on the public lands of this city; and be it said that if this city must have tierra de pan (land for bread) it is even more necessary that it have grassland for pasturing cattle. . . .
>
> May the Real Audiencia and Your Majesty grant the power to subdivide these Ejidos as I have suggested, which is with tax and perpetual rent for this city, to be paid each year, the amount of rent being determined and adjusted at the time of the subdivision according to the quality of the soil and the value of the land; in which acts I demand that justice be done.[5]

[3] Fray Alonsode Zamora, "Historia de la Provincia de San Antonio," Caracas, 1930, p. 255.

[4] Tulio Febres Cordero, Archivo de Historia y Variendades, Caracas, 1930, Vol. I, p. 183.

[5] Tulio Febres Cordero, "Decades de la Historia de Mérida," Mérida, 1920, Vol. I, pp. 170-172.

CLAY PIT WITH THATCHED ROOF AND BRICK KILN
IN THE PIT OXEN TRAMPLE THE CLAY TO THE PROPER CONSISTENCY. THE OWNERS OF THE KILN ARE BEGINNING TO USE COAL FROM THE MINE AT SAN CRISTOBAL.

THE WOOD HAS BEEN SPLIT; THE KILN IS BEING FILLED WITH LIMESTONE
IN ORDER TO BE READY FOR FIRING. DURING THE THREE DAYS AND NIGHTS NECESSARY IN THE BURNING OF SOME TWENTY TONS OF LIME, ALL THIS WOOD IS CONSUMED.

Nothing seems to have been resolved at the time, but during the colonial times the public lands gradually diminished in extent, the most powerful families taking the largest plots, until at present the Ejidos, known as Llano Grande, have been reduced to not more than an eighth of their original extent. Even as late as the nineties of the last century, when the question arose of selling some parts of the Llano Grande for the purpose of straightening boundary lines, the wall of the local legislature was decorated with these verses:

mass in the open before large groups of Indians. A convent was founded in 1567 and it received the tax on wine and oil from the Royal Treasury from 1570 on. The city was ecclesiastically in the jurisdiction of the Archbishopric of Santa Fé de Bogotá. Fray Rodrigo de Andrada, Prior of the Dominican Convent, had been a companion of Las Casas in his missionary labors as well as in his defense of the Indians against the greed of some Spaniards. Mérida was fortunate in having this humanitarian among her early churchmen.

OPEN MARKET IN MERIDA ON A MONDAY MORNING
NOTE DEFORESTATION ON THE SLOPES OF THE MOUNTAIN IN THE BACKGROUND.

La tela del Llano Grande	(The cloth of Llano Grande,
Es de trama singular,	Of very curious weave,
Es una tela inflamable,	Is an inflammable material
Peligrosa de cortar.	Dangerous to cleave.)

Fray Alonso de Andrada, of the order of Santo Domingo, came with Captain Suarez as chaplain, and was in Mérida from its founding. The Indians on the encomiendas received the Holy Faith from the Padres, who were wont to hold

Conquerors always wish to impose their language on the conquered. The conquering Romans in the Mediterranean world and the conquering Incas in Peru had this desire in common Carlos Quinto commanded that schools be founded in which Spanish be taught, and even decreed that the use of the native languages in the Nuevo Reino de Granada be prohibited. This decree was later annulled, and the priests were requested to learn the native dialects—a

YOKE OF OXEN ON THE MOUNTAIN TRAIL NEAR LA CULATA
DRAGGING A HUGE LOG TO THE LIME KILNS AT LA MILLA.

boon to the later students of the languages of the American Indians.

We read in Zamora, "But since insistence with assistance overcomes great difficulties, the padres, using interpreters, convinced those who opposed their teachings, and baptized many." As early as 1696, according to Zamora, the native language was little used around Mérida, yet as late as 1880 some of the

PEASANTS FROM LA CULATA ON THEIR WAY TO MARKET IN MÉRIDA

old pure-blooded Indians from outlying villages still conversed in the native dialect. But the present generation uses only Spanish.

In 1785 a school was established by decree of Carlos III under the headship of the Franciscan, Fray Juan Ramos de Lora. After many changes this became, in 1883, the University of the Andes, where at present three to four hundred students are matriculated, mainly in the colleges of law and medicine.

Thus Mérida has played the role of advance post in the diffusion of the Spanish language and culture as well as of the Roman Catholic faith.

Under Spanish hegemony there were four classes of subjects in Latin America: Spaniards born in Spain, who were qualified for all public offices and who enjoyed other special privileges; "criollos," people of Spanish blood, born in the New World, to whom the high government positions such as Viceroy, Governor, Captain General, were closed; Indians, who were directly governed by special officers within their tribes or towns, and who under no circumstances were eligible for any office except in governing their own people, who were considered somewhat as minors, or special wards of the colonial government; slaves, or Negroes, who, even if free, were a race deprived of all rights and privileges. They were not allowed to marry either Indians or Criollos.

The advantage of belonging to one of the first two classes mentioned above is readily seen by reading the regulation which was promulgated in 1789 by the Procurador of Mérida, Gerónimo Fernandez Peña:

> I command that no person of any class, state, or condition whatever carry weapons such as poniard, dagger, knife, or lance, under penalty, if the person be distinguished, of eight days in prison and four pesos fine; if the person be a plebian, fifty lashes and one month's forced labor, fettered with leg irons.

Undoubtedly one of the main reasons for the loyalty of the Criollos to the cause of the Revolution was their hope of being able to hold the good government posts. But when Bolivar envisaged a great Confederation of States the Venezuelan Criollos, fearful of losing privileges almost within their grasp, refused to recognize his authority, ousted him from Venezuela, and voted that his name be consigned to oblivion. In all justice it must be recorded that the first monument to Bolivar was erected in

A LIME KILN NEAR LA CULATA

THE PACK MULES ON THE TRAIL BEYOND THE HOUSE ARE LADEN WITH CHARCOAL FOR THE MÉRIDA MARKET. THE LOWER SLOPES OF THE MOUNTAIN BEYOND THE ALLUVIAL TERRACE ARE GRADUALLY BEING DEFORESTED.

Mérida in 1840, by the government of the Old Province of Mérida—an example of that independence of spirit which so often characterizes mountain communities.

The pre-conquest Indians of the Venezuelan Andes wore few clothes. Some wore narrow belts of cotton which were probably of Chibcha manufacture from

A NARROW BRIDGE OF NATIVE CONSTRUCTION

ACROSS THE TURBULENT UPPER MUCUJUN RIVER. THIS PEASANT WOMAN AND HER TEN-YEAR-OLD SON CARRY CANS OF MILK TO MÉRIDA EVERY MORNING—A FIVE-HOUR ROUND-TRIP.

TWO MULES LADEN WITH DOMESTIC CHEESE (*QUESO CRIDLO*) WHICH IS FROM THE TIERRA FRIA, ON THEIR WAY TO MARKET.

Bogotá. The Indians probably did not know how to make cloth.[6]. The Spaniards introduced looms, and employed many of the Indians of the encomiendas in small textile factories. The introduction of sheep made possible on a large scale the manufacture of woolen blankets. In 1832 the Governor of Mérida announced that the state was self-sufficient in the production of cloth. Even as late as 1870 cotton cloth was still manufactured in Tabay. In outlying villages, tributary to the Mérida market, such as Mucuchíes, Aricagua and El Morro, woolen blankets are still made, but mainly for local consumption. The outsider who wants a poncho, or covija, must order it a month or so in advance.

In the old geography books one reads that one of the most notable of the industries of Mérida was the manufacture of rugs and carpets, which were of excellent quality. The fine rug, in an excellent state of preservation, that covers the platform of the altar in the new chapel, Cristo de la Matriz, in Ejido, dates from 1815 or 1820. But the rug industry has completely disappeared.

It seems incredible, but as early as 1579 Mérida exported hams. It is not surprising that the first Spaniards in the Andes should have been interested in raising hogs, since they came from Estremadura in Spain, a province famous for its pork sausages; but that they should have been able to raise and fatten hogs in large quantities is the striking thing. What they were fattened on we are not told.

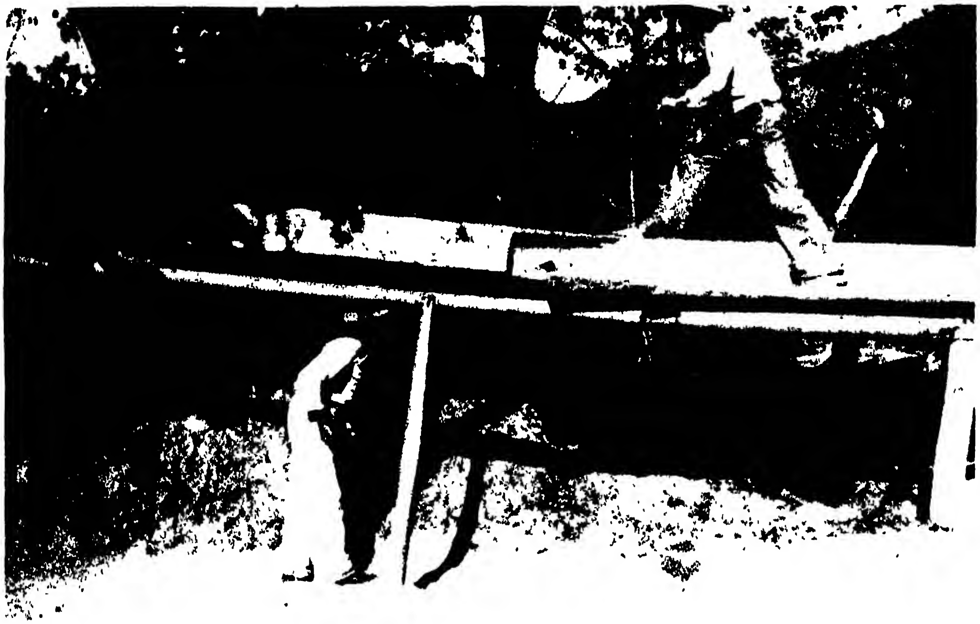
Formerly the manufacture of candy in the region of Mérida was a thriving industry. As late as the eighties sweetmeats and bon-bons were transported by mule trains as far as Tocuyo and Bauinas, at the edge of the Llanos.

Wheat, one of the first crops introduced into the Venezuelan Cordillera by the Spaniards, gave abundant yields and soon became an export crop. In 1579 two of the founders of Mérida promised the merchant Antonio Amezaga 1,000 arrobas (an arroba is 25 pounds) of flour at half a peso the arroba, laid down in any of the Lake Maracaibo ports. In the same year ships laden with flour biscuits and fruits coming from Mérida left ports along the south shore of Lake Maracaibo for Cartagena and the Antilles. Fray Pedro Simón, in speaking of the crops grown around Mérida, says, "but the most outstanding one is wheat, which gives heavy yields of good quality in the tierra templada (temperate region). Flour is shipped out to Cartagena by the frigates which enter Lake Maracaibo twice a year, calling at the port of Gibraltar, where it is stored in warehouses which have increased in number till the port has become a city. To-day it is the most famous port in the Indies because of the great quantity of fine tobacco which it exports from the city of Berinas."

But the methods of cultivating wheat have not changed in centuries. In Mucuchíes the fields lie fallow a year and are then again planted in wheat. Artificial fertilizer is little used because of the expense. There is very little animal manure to be had because of the small number of domestic animals. The ripe grain is trampled out on circular threshing floors by the hoofs of horses, just as it was in the time of the early Spaniards, and is to-day in many parts of the Mediterranean world.

After the War of Independence Venezuelan wheat was used only in the Andean provinces and in the neighboring states of Zulia, Lara and Barinas. It is estimated that in 1876 the State of Mérida produced 80,000 100-pound sacks of wheat, and as late as 40 years ago great quantities of wheat arepas (tortillas) were brought to the Mérida market from Mucumbá, Mucuchíes and El Morro, where they were sold at a penny apiece. With flour costing the equiva-

[6] Julio C. Salas, "Tierra-Firme," Mérida, 1908, pp. 44–45.



A PRIMITIVE LUMBER MILL NEAR MÉRIDA
IT TAKES TWO MEN A DAY TO SAW A TEN-FOOT LOG, 18 INCHES IN DIAMETER, INTO PLANKS.

lent of 8 to 10 cents a pound the arepa one could now buy for a penny would not make a small mouthful.

Cacao, cane sugar, indigo and cotton also were formerly exported from the Chama valley, but can no longer be produced cheaply enough to compete successfully with the large-scale mechanized production in other countries. Enough cacao and cane sugar are produced for local consumption. Indigo has long since been supplanted in its uses by the aniline dyes.

There is a reason for this decline in the exports of agricultural produce. Hams, flour and biscuits were produced by slave or serf labor and exported only to the mother country, in a closed economy. The Spaniards were not at all interested in the standard of living of the producers. When slavery and serfdom were largely abolished these products were consumed locally instead of being exported. The parallel with modern totalitarian economies is close. It is possible to export manufactured goods—or even agricultural products—in great quantities, if labor has only to be fed and housed, paid in last analysis out of the standard of living of those not producing for export. Since 1918 the mercantilist economy, streamlined for twentieth century consumption, has again become popular after a long rest.

On October 18, 1600, the Real Audiencea de Santa Fé voted 696 pesos to be used in building a church in Mérida. The man in charge of the construction was Don Juan de Milla, one of the first colonial architects in Venezuela. Don Juan built his brick, tile and lime kilns along the edge of the small stream which enters the Albarregas just east of the town, now known as the Milla. This was the beginning of those local industries which are still very important in the economic life of the town, and in which a great deal of local labor finds employment. Unfortunately, tremendous quantities of wood are used during the process

of burning and the use of coal from the mine at San Cristóbal is very recent. It now costs some $12 a ton laid down at the kilns. The great logs which are cut up for firewood are still dragged by oxen many miles over rough trails from the high mountains to the kilns for four Bolivares. It is to be hoped that this practice will be stopped before the forests are completely destroyed.

Mérida throughout its history has been a political and administrative capital. The town, separated by many weeks or, formerly, months from Bogotá, in whose jurisdiction it was almost till the end of the colonial period, soon achieved a kind of local autonomy. The central government, whether located in Bogotá or Caracas, was too far away to be consulted on every issue, so that the administrators themselves assumed the responsibility of making decisions on most local matters. But the salaries of government officials, both state and federal, have been important locally in fostering trade and industry.

One visit to the open market held every Monday morning will convince the visitor of the importance of Mérida as a trading center. Products of the several climatic regions arrive in trucks or on the backs of burros, oxen or human beings. From the tierra caliente down valley come plantains, melons, avocadoes, cherimoyas, medlars, cacao, yuca, arum roots and great pots of black paste, the tobacco extract known as chimo; the tierra templada supplies turnips, cabbages, tomatoes, beets, carrots, rue, cauliflower; potatoes, wheat flour, wool and huge cheeses wrapped in the velvety leaves of the giant dandelion, frailejón (*Espeletia Schultzi*), come from the tierra fria, the high cold mountain slopes. Thus the real role of Mérida is that of market town for a region composed of several climatic zones. It will never entirely lose its rural aspect. Small storekeepers and business men often have their real wealth in a piece, or several pieces, of land within a radius of 20 to 30 miles of the town. Many

A TYPICAL MOUNTAINEER IN FRONT OF HIS HOME

HE WAS AT THE UPPER LIMIT OF CULTIVATION ON THE LEFT BANK OF THE CHAMA, NEAR MÉRIDA. HIS FARMING TECHNIQUES WERE MOST PRIMITIVE: HE KNEW NOTHING OF CROP ROTATION, MADE NO USE OF FERTILIZERS, AND FOUND OUT WHERE CROPS DID BEST BY TRIAL AND ERROR.

MÉRIDA, WITH ROOF OF MOUNTAINEER'S HOUSE IN FOREGROUND
EVEN AT THIS ELEVATION PLANTAINS STILL GREW. THE PEASANT, FOND OF THE VIEW FROM HIS HOUSE, WAS HAPPY THAT ANOTHER COULD APPRECIATE IT TOO.

ranchers from the tierra caliente are happy to spend the less active years of their life in the mild climate of this Andean capital. They live in unpretentious homes on the quiet streets, and lead very peaceful lives, except in political discussion.

The tierra fria is a great human reservoir where large families are the rule-–families of 12 to 15 living children are common. In spite of terrible living conditions the infant mortality is relatively low. The air and water are pure; malaria and dysentery are unknown; the actinic rays of the sun are strong enough in the rare atmosphere to make rosy cheeks on dark skins. Crops ripen slowly, however, and the soil gives niggardly. In this purely agricultural region the population increase is much greater than the possible increase in the production of food. As the pressure of population increases there would seem to be only one safety valve, emigration, and there is only one direction to emigrate, and that is down. Very frequently the mountaineers settle on what the more fortunate people of lower-lying areas consider marginal land —along the upper limit of cultivation. Or they migrate to the towns, where they become skilled, industrious workmen. As Pedro Simón remarks, "The Andinos stand out above those of the other Spanish provinces in that both men and women are large of build, the children are healthy because of the temperate climate, and they have very keen minds." The most casual tourist is struck by the difference in appearance of the sallow, malaria- and dysentery-ridden people of the lowlands and the robust, energetic Andinos. Furthermore, one sees many old people in the mountains. An old person is a rarity in the lowlands.

During the past century almost every one who had soil on which coffee would grow planted that crop, considering it a kind of modern El Dorado. More and more land and energy were devoted to

the growing of coffee, whereas the raising of plantains, yuca, potatoes and cereals was neglected till they became scarce and correspondingly expensive. But one-crop systems of agriculture are apt to be instable, a kind of Damocles sword over the head of a nation. King Coffee was dethroned by nations of large-scale mechanized production. Many coffee plantations at present are being transformed into cow pastures, since in the past decade a ready market for dairy products has developed. Coffee can no longer be profitably exported except when heavily subsidized by the Federal Government, payments made possible in last analysis by the receipts from oil exports. When this source of income dries up the producer of foodstuffs will again play an important role in the regional economy. It is to be hoped that the "dead hand" of the system of latifundios, or great landed estates, will be partly or wholly lifted from the Chama valley—indeed from all of Venezuela.

The last important factor in the evolution of Mérida was the building, for wheeled vehicles, of the great Carretera Transandina, a part of the 2,295-mile-long Simón Bolívar Highway that stretches across Venezuela, Colombia and Ecuador from La Guayra to Guayaquil. (2,018 miles are completed and the remaining 277 are usually passable in fair weather.) Up to 1926 a trip from Mérida to Caracas was an ordeal lasting a week or ten days: three days on horseback to a Lake Maracaibo port, thence embarcation on a lake steamer to La Guayra. Now the trip can be made in motor car in two days. Since the completion of the Maracaibo-Mototán highway Maracaibo is only a day's ride from Mérida. One of the results of the linking up of Mérida by highways with the outside world is the development of tourism. It will benefit further when the Apartados-Barinas highway is completed. The increased movement has meant more money in circulation, and the most obvious result is the present building boom in the town, which is only beginning to reap the benefits of being in easy communication with the rest of the country.

In the Mediterranean world the area under cultivation around a town is often but the extension of the urban agglomeration, the founding of which took place in hoariest antiquity. Or it may be that the city does not have areas of intensive cultivation near it, as is true of Rome and Madrid. Such cities seem to the casual observer to have little geographic raison d'être. But in the mountains of Latin America the regional unit often sprouts, as it were, its own capital, particularly if the unit embraces various climatic zones or belts, as does the valley of the Chama River. The beautiful mesa on which Mérida is located, midway between tierra fria and tierra caliente, is an ideal site for inter-regional exchange. A detailed study of the valley of the Chama, from Mucuchíes to Laguinillas, only brings home to the student the fact that upon this mesa a town would almost inevitably come into being. One can not but admire the vision of the Indians, who were already well established there when the Spaniards came. And the Conquistadores were quick to realize that both the site and position were ideal for the development of an Andean capital.

Prefiero ser árbol, mejor que ser rama;
Prefiero ser leña, mejor que ser humo.
Y al viaje que cansa, prefiero al terruño;
La ciudad nativa con sus campesinos;
Ventanas arcaicas, vetustor balcones,
Y calles estrechas, como si las casas tampoco
quisieran separarse mucho.

(I prefer to be a tree, rather than a limb;
I prefer to be firewood, rather than smoke;
And to the tiring voyage, I prefer my homeland,
My native town and its farmers nearby;
Old fashioned windows and archaic porches,
And narrow streets, as if the houses themselves
wanted to keep close together.)

—*José Santos Chocano*

BIRD STUDY THROUGH BANDING

By Dr. DAYTON STONER
STATE ZOOLOGIST, NEW YORK STATE MUSEUM

WHEN Mrs. Stoner and I began banding bank swallows in 1923, we little thought that this work and the studies incidental to it would be continued for the succeeding eighteen seasons, or that 6,834 individuals of this species would be fitted by us with the numbered metal bands of the United States Bureau of Biological Survey (now the Fish and Wildlife Service of the United States Department of the Interior). Much less did we anticipate that we should be able to obtain 247 returns from the swallows that were banded by us, nor did we then suspect that our investigations would include such features as temperature of the birds and their burrows, weight of adults and young, food habits, behavior, longevity and family relationships. As a matter of fact, these and several new or little known matters relating to the ecology, life history and behavior of this swallow were suggested through the utilization of the banding method as the avenue of approach.

Our bank swallow banding work has been carried on in three rather widely separated localities, Lake Okoboji, Iowa, and Oneida Lake and Albany, New York. Of course one of our principal objectives has been to band as many individuals as possible so that the likelihood of recoveries might be correspondingly enhanced. In addition, we have attempted to utilize each recovery to the fullest extent and from several different view-points, but at the same time to avoid confusion and lack of progress by tempering the inclination to cover too much territory.

Before considering any of the concrete results of our bank swallow banding activities, it will be well to recount briefly the essential features in the life history of this bird. In this sketch I shall incorporate certain of our own findings as well as others more commonly known.

The bank swallow is a widely distributed, migratory bird which breeds from Alaska south to Texas and Virginia. It migrates through Mexico and Central America and winters in Brazil, Peru and Argentina. This swallow also occurs in Europe and the British Isles, where it is commonly known as the sand martin.

In the Oneida Lake, New York, region bank swallows usually begin to arrive late in April and attain maximum abundance by May 20. After a period of preliminary reconnoitering during which they course about over the countryside, pairing occurs and within a few days the birds take up nesting territory in the precipitous banks of streams and sand pits.

Excavation of the burrow is the first work to be accomplished, and both sexes take part in this activity. At first the swallows cling to the bank and peck away a few grains of sand at a time until a slight concavity is formed; using this as a point of vantage these energetic feathered excavators dig away with bill and claws until the future habitation acquires some length. As the loose sand

falls to the floor of the burrow it is literally kicked out by the swallows or sifted out by rapid movements of the partly folded wings.

The speed at which excavation is carried on depends somewhat upon the state of the birds' reproductive organs; ordinarily it progresses at the rate of 3 to 4 inches a day, for the average burrow which varies in length from 24 to 36 inches. The longest burrow that we have found measured 65 inches.

Nest construction follows immediately; this work also is shared by both sexes. The basic nest materials usually consist of grass and weed stalks—both green and dried—straw and rootlets; most of this is secured while the birds are on the wing. Some of the materials are so long —20 to 25 inches—and bulky that one wonders how so small a bird can manage such heavy and unwieldy objects.

Shortly after the unlined foundation nest is completed, the female sits in it preparatory to laying the eggs. During this period, as well as in the early stages of incubation, the male often sits on the edge of the nest by her side. The first eggs and sometimes all in the usual clutch of 4 or 5 are deposited in the unlined nest. As incubation proceeds, feathers usually white ones from the domestic fowl—are added as a lining so that by the time the young are hatched a cozy bed awaits them.

The eggs are white and the average weight is 1.4 grams. Fourteen to sixteen days are required for incubation; this activity is shared by both sexes.

At the time of hatching, the young are practically naked and small (average weight about 1.3 grams); for several days they require constant brooding, feeding and other care on the part of the parents. Body and feather growth are very rapid and maximum weight is attained in thirteen to sixteen days.

Usually the young attempt their first flight 19 to 21 days after hatching. In these initial attempts the birds exhibit remarkable wing control and maneuvering ability, but they lack endurance and do not long remain aloft. Although now adept in flight, for several days these immature swallows receive some degree of ministration from the parents. However, within a week the adults largely desert the burrows; a few resume nesting activities incident to the rearing of a second brood.

For a few days following initial nest-leaving the young make short flights into the surrounding territory. Although they usually continue to return to the home colony at night, they are as likely as not to enter other burrows as the ones in which they were reared. In other words, family relationships are more or less completely broken following first flight of the young. We have found immature banded repeats from as many as three different families in a single burrow. Gradually the young wander more widely and may roost in a colony some distance from the parental one. Within ten to fourteen days they desert the immediate scene of their natal home, and by August 1, or even earlier, begin flocking in swamps and similar situations preparatory to the southerly migratory movement which is often initiated a fortnight later.

Reasons for and Nomenclature of Banding

For several of the types of study undertaken by us and now to be mentioned in some detail, it was desirable that the birds be marked in some permanent manner so that, if and when they were subsequently recovered, we should be certain of their identity. The small numbered aluminum bands furnished by the U. S. Fish and Wildlife Service best meet the requirements.

A bird recaptured the same season that it was banded and in or near the territory occupied by it when banded is termed a "repeat." A bird recaptured at some distance from the point of banding in the same or a subsequent season

or in any locality after at least eight months have elapsed between the time of banding and the time of recovery or between two or more recoveries is designated as a "return." It is assumed that in each eight-month period the swallow completed the round-trip journey between its nesting territory and its winter home. If a return is captured more than once in a season it is called a "repeat return"; the second time that a bird is captured as a return it is designated as a "return-2," the third time as a "return-3."

Method of Capturing Bank Swallows

One of the advantages associated with the banding of bank swallows is that their nesting burrows can be utilized as traps to capture the occupants. Best success in capturing adults is likely to come during the height of the egg-laying period and the early days of incubation. In the Oneida Lake region we have found this to occur between May 20 and June 1. As indicated above, during this activity the male and female often occupy the burrow at the same time; not infrequently the pair can be taken together. In the later days of incubation usually only a single adult is found in the burrow at any one time.

Of course after the young are hatched the burrow also serves as a "gathering cage" for the bander. A small trowel may be used to carefully enlarge the burrow so that the investigator's hand and arm can be introduced for withdrawal and replacement of the nestlings. Young birds ready to fly can be flushed in the same way as the adults. Adult birds may abandon a nest if disturbed too much while it contains freshly laid or slightly incubated eggs, but only under extreme provocation will they desert one containing well-incubated eggs or young.

On cloudless days the observer, by using a small hand mirror, can throw a beam of light from the sun into the burrow, thus illuminating its interior sufficiently to count the eggs or birds and to study other features. On cloudy days an ordinary flashlight of the "pencil type" can be attached to a stiff wire and inserted into the excavation. If the burrow is found to contain adults a small gauze bag, held open at the large end by a ring of pliable wire, is quickly placed over the burrow mouth and fastened in place with two or three small hooked wires forced into the sand. After a longer or shorter period of watchful waiting, the swallows usually dart into the bag from which they are immediately rescued for observation and banding. Sometimes a little persuasion in the way of a long wire introduced into the burrow or the continued flashing of a beam of light into it with the mirror will cause the occupants to emerge. A light pounding on the turf above the burrow or on the face of the bank near its mouth sometimes produces the desired results.

Marital and Family Relations

Although, on the basis of external characters, it is impossible to distinguish the sexes in the bank swallow, we have banding evidence that both polygamy and polyandry sometimes occur in this bird. Moreover, in none of the several instances in which both members of a nesting pair have been captured as returns have we found the same individuals mated for a second time. While this swallow occasionally nests twice in a season, all of our return and repeat records indicate that new partners are taken for each nesting whether in the same or a different season.

Weight Studies

One of the important fields of ornithological investigation that has been stimulated through bird banding is the determination of the weight and its fluctuations for many species of wild birds. In most of our bank swallow work we use a triple-beam laboratory

THE OPERATOR INSPECTS THE INTERIOR OF A BURROW
WITH THE AID OF A BEAM OF LIGHT REFLECTED FROM THE SUN BY A SMALL HAND MIRROR. THE WHITE DOTS ON THE FACE OF THE BANK ARE TAGS BEARING BAND NUMBERS OF THE BIRDS INHABITING THE BURROWS. THE GAUZE BAGS, HELD IN PLACE BY WIRE HOOKS, COVER THE BURROW ENTRANCES, AWAITING THE BIRDS WHEN THEY FLUSH.

balance sensitive to $\frac{1}{10}$-gram and fitted with steel knife edges and agate bearings. To facilitate portability and render its use practicable and accurate on windy days, the instrument is housed in a wooden carrying case.

For 396 different adult bank swallows of both sexes captured between May 10 and July 20 the average weight was 14.3 grams, with a minimum weight of 11.8 grams and a maximum of 20.3 grams. Fourteen and three-tenth grams is the approximate equivalent of one-half ounce, or about the weight of four sheets of this publication.

From an average weight of 1.3 grams —roughly 1/28 ounce—at the time of hatching, young bank swallows attain the average maximum weight of 16.5 to 19.5 grams in 12 to 17 days. This is greater than the average weight of fully mature individuals.

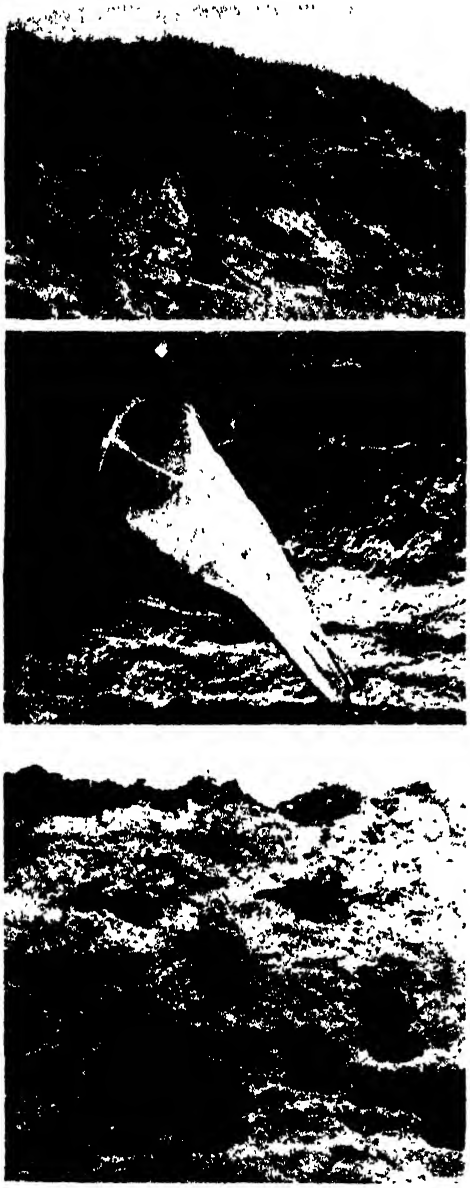
From about the sixteenth day after hatching to the time of leaving the nest the young lose from 1 to 4 grams in weight. And, even at the time of initial flight, they average heavier than the adults. This recession in weight during late nestling life characterizes all the swallows, but the phenomenon apparently is not shared by many other passeriform species.

Temperature Studies

In our investigations of the body temperature of bank swallows a specially constructed, non-self-registering mercury thermometer is used. This instrument is 6 inches long, $\frac{3}{16}$ inch in diameter and extremely sensitive Within a few seconds after it is inserted down the throat and into the proventriculus of the subject, it registers the temperature and thereafter, as long as it remains in place, any changes or fluctuations in bodily heat that may occur, without the "shaking down" so characteristic of the self-registering type of clinical thermometer used on human subjects.

The "normal" body temperature of most birds is considerably higher than that of man and the avian mechanism for regulating body heat is much less efficient than our own. On this account, rather remarkable variations and fluctuations in the temperature of birds may occur. It is perhaps more proper, therefore, to speak of "normal temperature range" in birds.

For adult bank swallows, the indi-



BANK SWALLOW BURROWS
Top: GROUP OF BURROWS NEAR THE TOP OF A HIGH BANK. *Middle:* A GAUZE COLLECTING BAG HANGS OVER A BURROW. THE TAGS AND SYMBOLS SERVE AS IDENTIFICATION MARKS. *Bottom:* A CLOSE VIEW OF SEVERAL BURROWS.

vidual variation in temperature may range from a minimum of 90° F. to a maximum of 112° F. Readings that we have taken on 734 different adult birds of both sexes at all hours of the day between 8 A.M. and 9 P.M. indicate that the average ("normal") temperature is 107.4° F.

At the time of hatching the young bank swallow is essentially a cold-blooded animal, just as were the reptile-like forms from which it has descended. Within a few days, however, its temperature control mechanism begins to function more efficiently and the body temperature becomes higher and more constantly maintained. We should expect to find, then, that variation in the temperature of young bank swallows is more marked than in adults. Our investigations have shown that a range of more than 25 degrees may occur in them, with a surviving maximum of 115° F. and a minimum of 90° F.

In order to illustrate the way in which the temperature of young bank swallows increases as they grow older, I present a brief summarization of our records. For this purpose the birds have been allocated into four principal age groups.

The average body temperature for 116 nestlings (age 1–4 days) was 99.8° F.; for 174 fledglings (age 5–9 days) 102.5° F.; for 89 juvenals (age 10–15 days) 104.5° F.; and for 122 immatures (able to fly well) 106.2° F.

It will be noted, therefore, that the average temperature for young birds at about the time they leave the nest is approximately one degree less than the average for adults, and that the average rate of increase in body temperature in young birds is about 0.5 degree a day until flight ability is attained.

Returns and the "Homing Instinct"

A little more than 4.5 per cent. of our banded bank swallows known to be available for returns have been recovered as such. Of course the assumed number of birds thus available in any season includes only those banded in previous seasons—less the number known to have

been killed or otherwise removed from consideration.

So far as we are aware no other person has ever captured one of our banded bank swallows. Moreover, the great majority of our return bank swallows have been recaptured by us in the same colony as banded. No individual has been taken at a greater distance than 12 miles from the point of banding; in the extreme case the bird was banded as a fledgling and recovered the next year as a breeding individual. Several of our recoveries have been "return-2's," that is, recovered as returns in two different breeding seasons but, to date, only one swallow carries the distinction—or ignominy—of having been captured as a return in *three* different seasons. A brief account of the known history of this bird will be of interest.

Incubating adult bank swallow No. F-55924 was banded from a burrow in the bank of a creek about three miles east of Oneida Lake, New York, on June 2, 1932. On May 26, 1934, it was recovered, incubating, in the same colony; on May 21, 1935, it was again recovered as a nesting individual in that colony; and on May 22, 1936, it was recovered, dead, in the same colony as before and in a burrow within a few feet of the one occupied by it in 1934. At the time of its death the known age of this bank swallow was 10 days less than five years; it had made at least five round-trip journeys between its nesting ground and its distant winter quarters and nested four seasons—at least three of them successive—in the same sector of the same colony; it had a different mate in 1935 and 1936; it was attacked and partially eaten by a brown rat as it was laying or incubating in a burrow within a few feet of the one occupied by it at the time of original capture.

Usually the bank swallow burrows of one season do not carry over to the succeeding nesting period. Weathering of the sandy soil causes the burrows to become obliterated either through filling up with sand or slipping of the banks. In at least two instances, however, we have found a banded swallow occupying the same burrow on two successive seasons.

One of our most interesting groups of returns was obtained in 1939 from five laying or incubating birds recaptured at one field station on an expanse of bank

ADULT BANK SWALLOWS
Top: TWO SWALLOWS LIE UNRESTRAINED IN THE OPERATOR'S HANDS. *Middle:* THIS BIRD WAS BANDED AS AN INCUBATING ADULT JUNE 13, 1938; RECOVERED IN THE SAME COLONY, BUT WITH A NEW MATE, JUNE 3, 1939. *Bottom:* A THERMOMETER IS INSERTED IN THE THROAT OF BIRD.

approximately nine feet long and six feet high. This is the greatest concentration of returns that we have encountered. Three of these swallows were banded in this colony in 1938 from burrows situated within a few yards of one another, while

the other two also were banded in 1938 but from rather widely separated burrows in a colony about one-half mile northwest of the point of recovery. It is interesting to speculate as to whether these birds remained more or less together during their migrating journeys and in their South American winter home and what—if anything—may have prompted three of them to return to nest in almost the same spot in the same colony which they occupied the preceding season while two others from a near-by colony took up nesting quarters in such close proximity to them. Surely something more than mere chance is responsible.

An analysis of our bank swallow return records indicates that first year birds do not often return to breed in the *colony* in which they were reared, but more frequently they do return to the *general region* of their nativity to rear their young. On the other hand, a large proportion of adults return to breed in the very colony in which they previously have nested and a still larger proportion return to the same general region after they once have nested there.

Here are the figures for the evidence: Of 35 birds banded as young and recovered as returns, only 9 (26 per cent.) had taken up domiciles in the same colony as reared. Of 212 birds banded as adults and recovered as returns, 170 (80 per cent.) were nesting in the same colony as banded. Furthermore, in each of the three localities where we have conducted bank swallow banding operations practically all our work has been done within a ten-mile radius wherein only 15 per cent. of the returns have been obtained from birds banded as young, while 85 per cent. of the returns have been derived from individuals banded as adults.

Longevity in the Bank Swallow

Bank swallows evidently are comparatively short-lived birds. Mortality among them appears to be very high, especially during the first year, while an individual that has survived to the ripe age of six years is a Methuselah of his kind. In the following tabular summary our 247 returns are grouped according to their known or approximate ages.

Approximate age	1 year	18
	2 years	146
	3 years	53
Known age at least	4 years	20
	5 years	9
	6 years	1

It would appear from this that the probable average life span in bank swallows is two to three years; only 12 per cent. of all our returns had attained a known age of as much as four years, while 80 per cent. of these returns are for individuals of a known age of two and three years.

Among the more important destructive agencies of the bank swallow, so far as both young and adults are concerned, may be mentioned slumping banks and the depredations of skunks. These animals frequently dig into the burrows from above and feed on eggs and birds of all ages. Foxes sometimes dig into the nests from the face of the bank, and swallows nesting in the vicinity of farm buildings are often attacked by brown rats which climb the slightly sloping or rough banks to enter the burrows and feed on the birds in all stages from egg to adult. Crows and marsh hawks are serious enemies of bank swallows during the nesting season, when they attack the adults while they are carrying food to the young or leaving the burrows after delivering it to them.

The several types of inquiry that we have conducted on the bank swallow through use of the banding method, not only have contributed to our knowledge of this bird but also may suggest lines of endeavor that can be undertaken with profit on other species. Worthwhile results are sure to attend earnest effort.

RADIATION PATTERN OF THE HUMAN VOICE

By D. W. FARNSWORTH
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Radio antennas, microphones, loudspeakers, or any apparatus that either emits or receives radiations has a directional characteristic or radiation pattern, and the determination of these patterns is one of the routine procedures in radio and acoustical work. If the device is to receive radiation, the directional characteristic expresses the sensitivity of the device to radiation coming from various directions in space. If the device is to emit radiation, on the other hand, the directional characteristic expresses the power radiated in various directions. In both cases the sensitivity and power in each measured direction may be subdivided into frequencies or frequency bands. In acoustics, the basic radiator of voice sounds is the human mouth, but strange as it may seem there are no known records of any complete determination of the directional characteristic of speech as it is affected by the shape of the mouth, head, and body. This situation has now been partially remedied by an extensive study recently made in these laboratories by H. K. Dunn and the writer.

Perhaps one of the reasons that such a study has not been made before is that it is inherently a much more laborious task than determining the directional characteristics of a loudspeaker or microphone. With a loudspeaker, for example, the characteristic is usually determined for a number of single frequencies, and these are supplied to the loudspeaker from an oscillator giving a continuous tone at constant frequency and volume. There are no other variables but the position of the pick-up microphone, and thus the procedure is comparatively simple. The human voice, however, is a complex assembly of different frequencies at different levels, and in ordinary speech both level and frequency composition vary continuously. Moreover, the source is a human throat, which suffers fatigue; it can not be turned on like an oscillator and run continuously without variation. Determining the distributional pattern of the voice is thus far more laborious and complicated than any of the more usual determinations of directional characteristics.

In securing the spatial distribution pattern of speech, it seemed desirable to average the speech pressures over an interval long enough to insure that the average was typical, and to use as the source of sound a set of words that would be typical of ordinary speech both in the basic sounds employed and in their distribution into syllables. To meet this requirement, J. C. Steinberg devised the following sentences. "The different speech sounds have been moulded into (sentences, such that the consonants and usual compounds occur in the vowel combinations which are met with very frequently in English. For lack of time, it was not possible to get every group included; although, as is shown quite clearly in the figure upward of eighty per cent.) are accounted for. I think nothing else need be said in this place on the subject." Sound pressure was averaged over a 15-second period, which was controlled automatically, and the actual measurement usually covered about that portion of the above quotation included in parentheses. The tests were made in an acoustically treated room so that reflections from the walls would not result in readings that did not

truly represent the direct radiation from the mouth. Because of these precautions, the results are essentially the same as would have been obtained in an open outdoor space entirely free from extraneous sounds.

Besides determining the distributional pattern for whole speech, it was desired also to determine it for various bands of frequencies. In some ways, the

FIG. 1. TEST CHAMBER
ARRANGEMENT OF SPEAKER AND MICROPHONE FOR DISTRIBUTION MEASUREMENTS.

narrower these bands, the more satisfactory would be the results, but it was finally decided, largely because of the availability of filters, to divide the range of speech frequencies into twelve bands. The lowest three were each one octave wide, and ran from 62.5 to 500 cycles, while above 500 cycles, the filters were each one-half octave wide except the twelfth, which was a high-pass filter cutting off at 8,000 cycles. The upper frequency is really set by speech itself, which has practically no components above 12,000 cycles.

Limitation of apparatus and of personnel made it necessary to take readings at only one position in space at a time, and of only two frequency bands. This meant, of course, that measurements would have to be carried on over a considerable period of time, since for each of some eighty positions in space seven readings were required to cover all the frequency bands and eight readings were taken for each pair of bands to insure that the value used was representative. Including preliminary and trial readings, a total of 5,000 readings was taken altogether.

With such a protracted study, there would be bound to be variations in the test sentences in volume, not only from day to day but for different sets of readings taken on the same day. It was necessary, therefore, to set some reference volume at some fixed position, and to correct each set of readings for departures from the basic value. To make this possible two pick-up microphones were used for each reading; one was an exploring microphone, which could be moved to the various positions in space, and the other was a fixed microphone. This latter microphone was fastened to the arm of the chair in which the speaker sat, with the diaphragm at one side and slightly below the speaker's lips, and 32 centimeters away. A bracket attached to this transmitter carried a small loop of wire at the end, and the speaker always sat so that this loop just touched his upper lip. The arrangement is shown in Figure 1.

Both of the microphones were of the condenser type with self-contained amplifiers. They are small microphones with diaphragms only 1.8 centimeters in

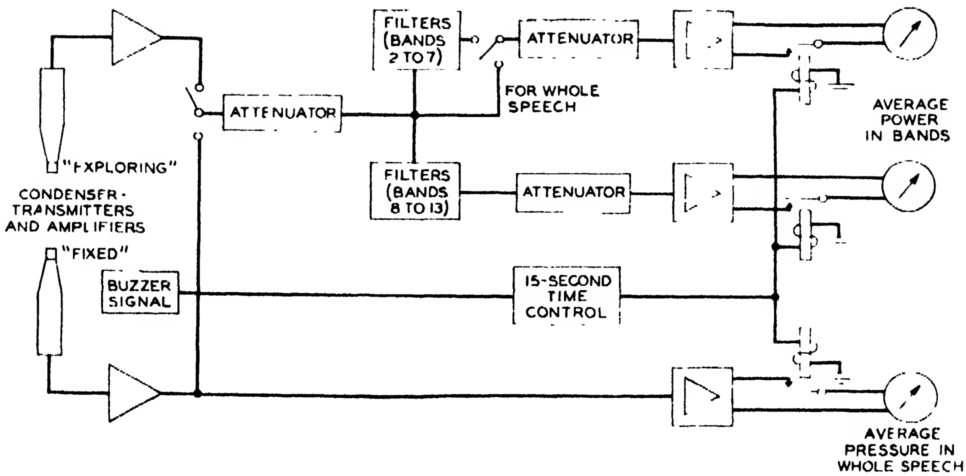

FIG. 2. BLOCK SCHEMATIC OF MEASURING CIRCUIT

diameter, but for positions very close to the speaker's mouth, a "search tube" five centimeters long and only three millimeters outside diameter was used. A block schematic of the testing circuit is shown in Figure 2. For each position of the exploring microphone, four readings would be taken for each frequency band and for whole speech, and four for each band using the fixed transmitter.

Positions in space at which readings were taken are designated by three coordinates, as indicated in Figure 3. One of these, designated "r," is the radial distance in centimeters from the front of the lips; another is the horizontal angle "θ" measured from directly in front of the speaker in either direction around to 180°, directly behind him. Readings were taken only around one side, since it seemed reasonable to assume that because of bodily symmetry, readings on the other side would be the same. The third coordinate is the verti-

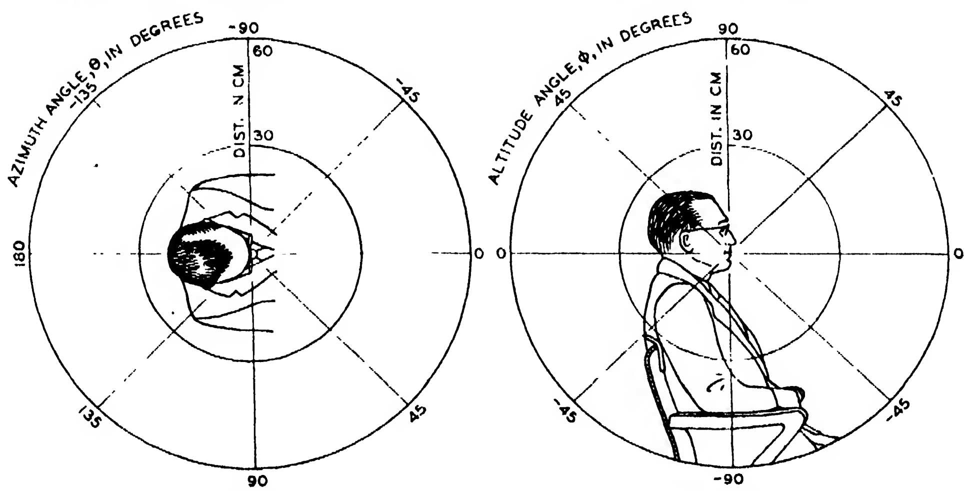

FIG. 3. POSITIONS IN SPACE INDICATED BY THREE COORDINATES:
R, RADIAL DISTANCE FROM THE LIPS; θ, HORIZONTAL ANGLES, AND φ, VERTICAL ANGLES.

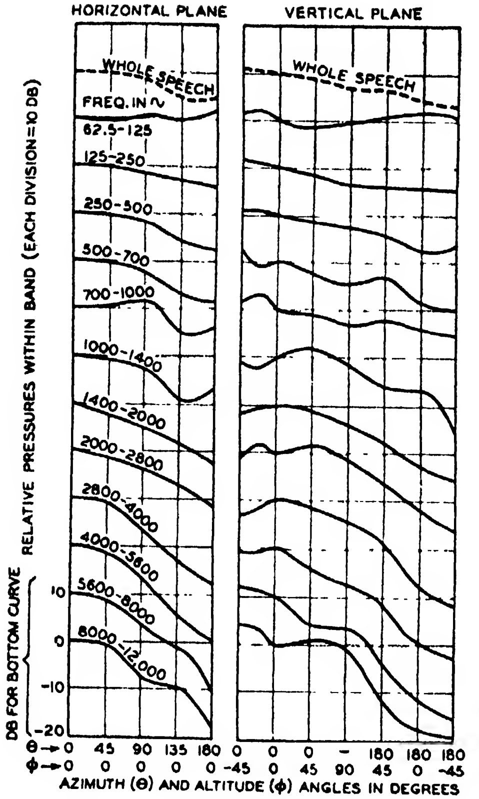

FIG. 4. SPEECH PRESSURES
AT 60 CM FROM THE LIPS AS θ VARIES, AT THE LEFT, AND AS φ CHANGES, AT THE RIGHT.

cal angle ϕ, measured from zero in the horizontal plane to +90° directly overhead, and to −90° directly beneath the lips.

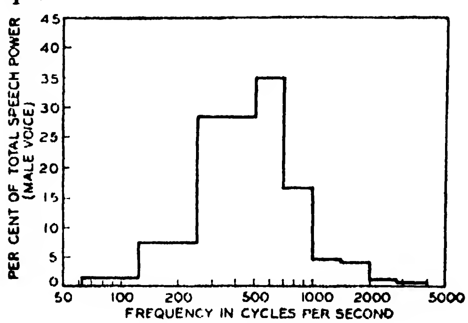

FIG. 5. MALE SPEECH POWER
SPECTRUM OBTAINED FROM AN INTEGRATION OF THE TEST RESULTS. THESE CALCULATIONS ARE PLOTTED IN PER CENT. OF THE TOTAL POWER.

With data distributed over three-dimensional space and over twelve frequency bands, it is difficult to present them in a way to make the distribution of sound pressures evident over the entire volume. The general form of distribution may be indicated, however, by plotting the pressures at some one constant radial distance for each frequency band and for speech as a whole at vertical angle 0° as the angle θ varies from 0 to 180°, and in a vertical plane at horizontal angle 0° as the vertical angle varies. This is done in Figure 4.

Considering first the variation with horizontal angle, it will be noticed that whole speech remains about constant up to 90°, and then falls off. Frequencies from 62.5 to 175 cycles, however, remain practically constant all the way around. For the higher frequency bands there seems to be a progressively increasing reduction in level after angle 45° is reached. This becomes particularly pronounced for frequencies above 2800 cycles. Pressures at frequencies from 700 to 1400 cycles seem to behave in a rather anomalous manner, for which there is no ready explanation. It has been known, of course, that in general the high frequencies are more directional than the low, but this is the first time that actual detailed results have been secured of their directivity when emitted as speech.

Distribution in the vertical plane, shown at the right of Figure 4, evidences more unexpected characteristics. For whole speech and all frequency bands below 1000 cycles, and also for frequencies above 5600 cycles, the pressures are greater at an angle of 45° below the horizontal than they are in the horizontal plane. At a distance of 15 cm where readings may be taken at −90°, or directly below the lips, the pressures straight downward are greater than either at −45° or 0° for all frequencies below 1000 cycles.

Data of this sort are very useful in guiding the placing of microphones, since they show the region over which all frequencies are present in about their true relative proportions, and the amount of equalization that would be required in other locations. A study of these curves shows that a microphone could be placed at any horizontal angle up to about 75° and at any vertical angle from −45° to 90° without the necessity of equalization.

To confirm these conclusions, listening tests were made in which two other positions were compared with a position in front of the speaker. One of these was 60 cm directly above the lips, the forward transmitter being at the same distance, and listeners in another room could switch between the two transmitters. After equalizing the two circuits for loudness, the listeners could not distinguish between the two transmitters. When one of the transmitters was placed directly behind the speaker, however, there was a marked loss of the higher frequencies.

Another advantage of these data is that they may be used for calculating the total voice power, and also the total power in each frequency band. By assuming that the pressure in each direction represents the average pressure extending half way to the next position line in both directions in both horizontal and vertical planes, it is possible to integrate speech pressures over the entire surface of a sphere having its center at the speaker's mouth, and by using a suitable constant to calculate the total emitted power. The error in this basic assumption is probably within the accuracy of the test data. The results of these calculations are plotted in Figure 5 in per cent. of the total power. This

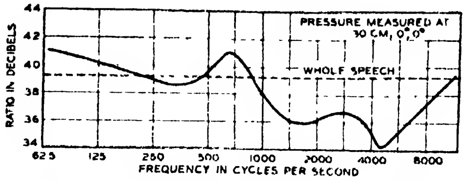

FIG. 6. AVERAGE SPEECH POWER

RATIO OF POWER IN TOTAL FIELD TO THE POWER PER SQUARE CENTIMETER AT A SINGLE POINT.

curve shows that for the male voice tested, 80% of the total speech power is in the frequency band from 250 to 1000 cycles; that 96% is in the band from 125 to 2000, and that only 0.4% is above 4000 cycles.

Previous to these tests, a common method of estimating total speech power was to assume that the pressure directly in front of the speaker was constant over a hemisphere. A similar calculation made from data taken on these tests gives a result 2 db lower than that obtained from the more complete integration. Although the total speech power will vary with the person talking, this difference for the two methods of calculation should remain constant, and so it is safe to assume that calculations made on the basis of a single reading in front of the speaker have been about 2 db too low.

This ratio of total speech power to the power per square cm at one point was calculated for all the frequency bands as well as for whole speech. A curve expressing this ratio for a point 30 cm directly in front of the speaker's mouth is given in Figure 6. Such a curve may be drawn for any of the points at which measurements were made, but the shape of the curve would vary with the point taken. With such curves available, the total speech power may be determined from measurements made at a single point.

JEWISH PRODUCTION OF AMERICAN LEADERS

By Dr. MAPHEUS SMITH and RASHEY B. MOTON
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MANY of the most eminent men of history have been of Jewish extraction, among whom the names of Spinoza, Disraeli, Ferdinand Lassalle, Heine, Ricardo, Marx, Moses Mendelssohn, Felix Mendelssohn and Jacques Offenbach are among the most prominent. Of contemporary eminent men of science and philosophy Einstein, Bergson, Ehrlich and Freud take the front rank. In the theater such actresses and actors as Rachel, Bernhardt and Muni, and such producers as Belasco and Reinhardt immediately come to mind as bearers of a great tradition. Most of the current masters of the violin are Jews. A number of leaders in law and government also represent the group, including Secretary of the Treasury Morgenthau, Supreme Court Justice Frankfurter and the recent Justices, Cardozo and Brandeis. In philanthropy the names of Guggenheim and Rosenwald are among the most notable. And such Jewish families as the Rothschilds in finance, the Flexners in education and medicine and the Lévys and Helévys in France, famous in a variety of fields, demonstrate that Jews have talent in all fields of endeavor. Several hundred other eminent persons might be named, if both historical and contemporary groups[1] are included.

Long ago Lombroso made a strong case for the Jews as a "race" of genius, saying the European Jew is superior to the African and Asiatic members of the group.[2] Sorokin reported Jews to be well represented among American millionaires,[3] and Davis found that Jews were three times as numerous among Russian communist leaders as their proportion in the total population would lead one to expect.[4] Cattell mentions the intellectual prominence of the Jewish group, seven of the leading one hundred American scientists in 1903 and 1906 being Jews;[5] and Roback reminds us that fifteen of the Nobel prize winners up to 1927 were Jews or of Jewish descent.[6] And according to Joseph Jacobs's estimates, Jews, during the century from 1785 to 1885, surpassed Englishmen in per capita production of "illustrious" and "eminent" men, but were surpassed in production of "distinguished" persons.[7] It is therefore clear that in the past and present Jews have not only made many outstanding contributions, but their production of leaders has always been proportionate to or above what should be expected when we consider their numbers in the total population.

Throughout the years since prominent people have been studied as a class, there has been no attempt to determine the contribution of American Jews to the

[1] A. A. Roback, "Jewish Influence on Modern Thought," Cambridge, Massachusetts, 1929, for a discussion of eminent Jews.

[2] Cesare Lombroso, "The Man of Genius," pp. 133–136. London, 1891.

[3] P. A. Sorokin, *Jour. Social Forces*, 3: 627–640, 1925.

[4] Jerome Davis, "A Study of One Hundred and Sixty three Communist Leaders," Publications of the American Sociological Society, 24, 45, 1930.

[5] J. M. Cattell, editor, "American Men of Science," pp. 783–784, 1921. Out of 738 families mentioned specifically thirteen were Jewish on both sides and one was Jewish on one side.

[6] *Op. cit.*, p. 219.

[7] Joseph Jacobs, *Jour. Anthrop. Inst. of Great Britain and Ireland*, 1886, 15, 251–279. Galton's procedures for selecting eminent persons were employed.

total list of eminent personages in the United States. But some data on this subject, obtained from "Who's Who in America," 1938–1939, and "Who's Who in American Jewry," 1938–1939, are for the first time available. A check of the entire "Who's Who in America" list was made against the entries in "Who's Who in American Jewry," a total of 1,112 names being found in both lists. An additional 20 names not found in "Who's Who in American Jewry" reported Jewish religious affiliation in "Who's Who in America," making a total of 1,132 Jews included in the larger list. This total, which is to be considered a minimum figure, is equivalent to one "Who's Who in America" Jew to each 4,212 Jews in the population of the United States in 1938.[8] Since the corresponding ratio between the total names listed in "Who's Who in America" and the estimated United States population of 1938 was 4,140,[9] Jews are approximately as well represented as non-Jews.[10]

Although they are represented up to expectancy in the "Who's Who in America" group, the Jewish contribution of prominent Americans is not as high as should be expected of a group having their opportunities. In view of the fact that Jews in the United States have been and are almost exclusively urban residents (99.1 per cent. of all members of Jewish congregations in 1936[11]), and the fact that persons born in cities or living in cities have more chances for eminence than those born in or residing in rural areas,[12] Jews should be expected to surpass the average of the United States population in contributing to the list of eminent personages. The reason they fail is that they must overcome a variety of serious handicaps. One which they face in common with other large population groups is the large proportion of them who are foreign born. In general the foreign-born population has less than half as much chance for high social recognition as the native-born population.[13] The Jews have overcome this handicap and have made a much better showing than many other large immigrant groups which have taken up an almost exclusively urban residence, for example, Italians, Poles and Greeks,[14] but they have not accomplished more in this respect than some other immigrant groups which were forced to learn a new language, for example, French, Dutch and Icelanders.

Other handicaps that have had to be overcome are the poverty of a large part of the Jewish group; the strong isolationist tendencies characteristic of persecuted minority peoples, in this case deriving from their history in other countries; differences in social status between the German groups who arrived early and the Russian groups which came later; and the various forms of discrimination all have faced. Discrimination has been a special obstacle in some fields, particularly those which would involve personal relationships of social or administrative superiority on the part of

[8] Based on an estimated 4,768,352 Jews in the United States in 1938. The estimate was derived from the 1936 religious census report of Jews (4,641,184 persons, "Census of Religious Bodies, 1936," *Bulletin* No. 72, "Jewish Congregations," Washington, 1940, p. 2) corrected by the addition of 127,168 persons who were added, on the assumption that the 1926–1936 percentage rate of increase among United States Jews was continued for an additional two years.

[9] The 1938 mid-year population estimate of the Census Bureau was employed.

[10] Actually the Jews are slightly below expectancy among the "Who's Who" names, but there may be sufficient error in the reports to bring the group up to a proportion among the eminent equivalent to that of its population in the country.

[11] "Jewish Congregations," p. 1.

[12] See the summary in P. A. Sorokin, C. C. Zimmerman and C. J. Galpin, "A Systematic Source Book in Rural Sociology," Volume III, pp. 296–304, Minneapolis, 1932.

[13] Mapheus Smith, *Sociology and Social Research*, 20: 424–426, Table I, 1936.

[14] *Ibid.*

Jews over people of the older American stocks. The group has thus been handicapped in teaching, in government and in the military services, all of which provide comparatively numerous opportunities for the highest recognition.

Attempts to account for the ability of the Jews to overcome their various handicaps will fail unless we go beyond their urban opportunities, which are to some extent cancelled out by the poverty of the group. It is necessary to discover other and more positive considerations, if their contribution to American leadership is to be adequately understood. One of the most important questions is that of Jewish intellectual ability. Data clearly establish the slight intellectual superiority of Jews over non-Jews in cities in the United States, as well as in London. Studies of several thousand children in London disclosed an IQ superiority at each age from 8 to 13 years.[15] In eight studies made in the United States and summarized by Pintner in 1931 four showed superiority for the Jews, three for the non-Jews and in one the two groups were equal.[16] In addition, Jewish students have been found to score higher than non-Jews in the Thorndike Intelligence Test, in college marks and in the Moss Social Intelligence Test.[17]

The evidence on the intellectual variability of the Jews is also indicative of superiority. Terman found that children with at least part Jewish blood were twice as numerous in his group of superior children as Jews were in the population of the localities covered by the study,[18] and they held their own in the follow-up studies, although the total group of children declined slightly in IQ.[19] Hollingworth also says that Jewish children are often very superior in intellectual status. Indeed, three of nineteen cases of children testing above 180 IQ were descended from Jewish families on both sides,[20] which means that a larger proportion of very intelligent children are Jews than would be expected on the basis of the size of the Jewish population. The exact superiority is impossible to determine, however, owing to the fact that the Jews, being an urban people, are more likely to be discovered by mental testers. The small number of cases makes it very unsafe to generalize further than to say this evidence is consistent with all the other data. Both in average intellectual status and in variability in the superior intellectual range the Jews are equal or superior to the mass of the non-Jews.

Jews are more susceptible to mild insanity than most other groups. This has been mentioned by Lombroso and others,[21] and, when considered in relationship to general ability, is in line with the theory of biological variations as the

[15] M. Davies and A. G. Hughes, *British Jour. Psychol*, 18: 134–146, 1927; and A. G. Hughes, *Eugenics Review*, 20: 89–94, 1928.

[16] Rudolf Pintner, "Intelligence Testing," pp. 453–454, second edition, New York, 1931. More than 2,500 cases were included in these studies.

[17] H. E. Garrett, *Personnel Jour.*, 7: 341–348, 1929.

[18] L. M. Terman, "Mental and Physical Traits of a Thousand Gifted Children," pp. 55–56, Stanford University, 1926. Also see P. A. Witty, Yearbook of the National Society for the Study of Education, 39, Part II, 401–409, 1940.

[19] B. S. Burks, D. Jensen and L. M. Terman, "The Promise of Youth," p. 54, Stanford University, 1930. Also see L. M. Terman and M. Oden, "Correlates of Adult Achievement, in the California Gifted Group," Yearbook of the National Society for the Study of Education, 39, Part I, 81, 1940, for the statement that a larger proportion of Jews were in the highest 25 per cent. of the gifted group than in the lowest one fourth.

[20] L. S. Hollingworth, "Gifted Children," pp. 70–71 and Chapter IX. New York, 1927.

[21] Lombroso, *op. cit.*, pp. 136–137; J. Slawson and M. Moss, *Jewish Social Service Quarterly*, 12: 343–350, 1936.

explanation of both phenomena.[22] Jews are also well adapted emotionally to achievement[23] and are very aggressive in many ways. The persecution of the group, their continued intermarriage, and the possibilities of social selection also can be fitted into a hereditary interpretation of their superior production of eminent personages.

On the other hand, it must be strongly emphasized that mental ability and temperamental traits do not bear a perfect relationship to achievement nor achievement to social recognition. The social factors of tradition, early training and continued focus on success and leadership must be accorded great weight in the total explanation of the Jewish contributions to eminence. For example, there is a powerful tradition of striving for achievement and a powerful stimulus to success. This is reflected in all parts of the Jewish family and community, as the following description indicates:

No Jewish boy was allowed to grow up without at least a rudimentary knowledge of Hebrew. The scantiest income had to be divided so as to provide for the boys' tuition. To leave a boy without a teacher was a disgrace upon the whole family, to the remotest relative. . . .

My brother was five years old when he entered on his studies. . . . After a boy entered heder, he was the hero of the family. He was served before the other children at table, and nothing was too good for him. If the family were very poor, all the girls might go barefoot, but the heder boy must have shoes; he must have a plate of hot soup, though the others ate dry bread. . . . It was not much to be a girl, you see. Girls could not be scholars and rabbonim.[24]

In the case of the Jews there is also an element of group conflict arising from prejudice and oppression, on the one hand, and pride in group achievement, on the other hand. And also to be considered is the factor of high intensity of social contact and interaction in the urban habitat. The various social conditions mentioned suggest that a large part of the group's production of eminent men is due to non-hereditary psychological and social factors.

Occupations of Prominent Jews

The occupational distribution of prominent Jews differs in important respects from that of the total "Who's Who in America" group (Table I). Jews surpass non-Jews in the theater, painting and sculpture, law, music and social science. They are at a disadvantage in agriculture, architecture, education, engineering, library and museum leadership, military affairs, natural science, political and civic leadership and religion.

TABLE I

Occupational Distribution of Prominent American Jews, 1938–1939

Vocation	Jews Number	Jews Percentage	Non-Jews Number	Non-Jews Percentage
Actors, producers	37	3.3	189	.6
Agriculturists, foresters, etc.	0	0.0	185	.6
Architects	7	.6	253	.8
Artists (painters, sculptors)	50	4.4	893	2.8
Authors	115	10.2	2,771	8.8
Bankers, financiers	50	4.4	1,021	3.3
Business proprietors and executives	122	10.8	2,507	8.0
Doctors of medicine	134	11.8	2,166	6.9
Educators	101	8.9	5,373	17.1
Engineers, inventors	24	2.1	1,172	3.7
Journalism, publishing	66	5.8	1,837	5.8
Lawyers, jurists	165	14.6	3,552	11.3
Librarians, curators	5	.4	266	.8
Military leaders	0	0.0	540	1.7
Miscellaneous	4	.4	114	.4
Musicians	65	5.7	592	1.9
Natural science	44	3.9	1,709	5.4
Public officials, civic leaders, social workers, etc.	54	4.8	2,467	7.9
Religious leaders	60	5.3	3,299	10.5
Social scientists, statisticians	29	2.6	548	1.7
Total	1,132	100.0	31,454	100.0

These conclusions are in most respects in agreement with those of Jacobs, whose study a half century ago was based on historically important personages of Europe covering the period 1785–1885 (Table II). Lack of agreement between

[22] Havelock Ellis, "Man and Woman," pp. 450–457. Boston, 1929.

[23] *Cf.* L. S. Hollingworth and M. M. Rust, *Jour. Psychol*, 4: 287–293, 1937.

[24] Mary Antin, "The Promised Land," pp. 32–33. Boston, 1912.

TABLE II

JACOBS'S OCCUPATIONAL CLASSIFICATION OF EMINENT EUROPEANS AND JEWS[25]

	Europeans	Jews
Actors	2.1	3.4
Agriculture	.2	0.0
Antiquaries	2.3	2.6
Architects	.6	.6
Artists	4.0	3.4
Authors	31.6	22.3
Divines	13.0	10.5
Engineers	1.3	.9
Engravers	.3	0.0
Lawyers	4.4	4.0
M.D.s	3.1	4.9
Merchants	1.2	4.3
Military	5.6	.6
Miscellaneous	.4	.3
Metaphysics	.2	1.8
Musicians	1.1	7.1
Natural science	2.2	2.5
Naval	1.2	0.0
Philologists	1.3	12.3
Political economy	2.0	2.6
Science	5.1	5.2
Sculptors	1.0	1.2
Sovereigns	2.1	0.0
Statesmen	12.5	8.3
Travelers	2.5	1.2
Total	101.3	100.0

the studies is evident in only five items in which direct comparison is possible, while there was agreement between the studies in the theater, agriculture, religion, engineering, medicine, music, business, military affairs, social science and political and civic leadership. In Jacobs's study Jews were at a disadvantage in painting and sculpture, authorship and law, at an advantage in natural science, and neither at a disadvantage nor an advantage in architecture.

As with total group differences in achievement, hereditarian interpretations are frequently made of differences between groups in kinds of achievements. Thus, it is possible to argue that Jews possess superior natural ability in the arts, on the suppositions that talent is associated with interest and other motivating forces and that a combination of talent and motivation inevitably produces proportionate achievement and fame. However, each of the suppositions in this chain of inference is subject to question. It is not certain that population groups differ in musical or other talents, nor is it certain that talent, unaffected by other facts, produces motivation to achievement. Furthermore, it is well known that minority groups, prevented by the traditions and active pressures of the majority group in a social order from equal participation in all vocational fields, tend to find expression for their abilities in the arts. As a result ordinary artistic talents may be expected in time to receive unusually vigorous expression and to give the impression of a high level of hereditary artistic talent in the group.

What is needed before a correct evaluation of the differential vocational achievements of groups can be made with assurance is information on the opportunities for achievement and recognition in various fields. A major statistic required is the total occupational distribution of various population groups, in this case, of Jews and non-Jews in the United States. We do not know whether Jews, in proportion to their appearance in those occupations, are superior in the arts or whether they seem to stand out because so much larger a proportion of the total employed in the arts in the United States are from the Jewish group. Even in the absence of such data, however, it is possible to suggest some hypotheses to account for the vocational differences revealed in Table I, although these hypotheses can not be fully evaluated until more information is available on special abilities, interests, discrimination, occupational data and avocational activities.

The traditional element in Jewish artistic, banking and business accomplishments is particularly large. In the theater and in music there has for a long time been a strong Jewish emphasis, and these have been extended with the development of motion pictures and radio.

[25] Jacobs, *op. cit.*, p. 363. The data from which these figures were obtained were not presented, and it is therefore impossible to correct the figures for Europeans to take care of the excess in the percentages.

From prominence in the theater and music the spread of interest and leadership to other arts is readily understood. Literature offers an opportunity for minority groups, because of the generally indirect relationships between the author and the public. Leadership in banking and business is to some extent explained by Jewish leadership in these fields during ancient and medieval times, and the traditional extension to the present. It is also likely that small opportunities for Jews in some fields, such as the higher political positions, the colleges and universities, libraries and museums and military affairs have caused them to concentrate in such learned professions as law and medicine, as well as in the arts and business.

Few American Jews live in rural districts, and practically no large-scale agricultural operators are found among them. The disadvantage of the Jews in such practical pursuits as architecture and engineering is not clearly understood, but probably is explained by lack of interest in such professions, rather than by discrimination. The same argument applies to some extent to the natural sciences, in which Jews showed up to such great advantage in Jacobs's study of Europeans. In political and civic life and in military affairs we can see the effects of prejudice and discrimination directed toward a minority group predominantly made up of recent immigrants, living in the centers having strongest foreign ties. The Jewish American is also to some extent discriminated against in education[26] and library and museum leadership. The group's disadvantage in religious leadership is probably explained by the ratio of religious leaders to all people among the Jewish and non-Jewish populations, some of which may be due to the concentration of the Jews in urban areas where there may be relatively few rabbis to the total people in the community.

It should be emphasized again that our knowledge of the facts associated with the listing of persons as prominent are too limited to certify the factors responsible for the general and occupational contributions of the Jews to a group of notable Americans. The only thing reasonably certain is that the explanation is complex. No single factor explains any of the rates of production. And we do not even know that social or environmental factors are adequate to the exclusion of hereditary ones. But it seems clear that major weight should not be given to heredity, since such matters as interest, discrimination, opportunity and tradition seem to be of most significance.

The facts reviewed in this paper are of particular importance at this time, because of the tendency for each minority group to be given special attention when a critical situation faces a nation. Generally some one minority group will be singled out as a special object of hatred or overt violence, being blamed for conditions for which it is in no way responsible. Sometimes this is done deliberately by demagogic leaders, but such an interpretation frequently is borrowed by a leader from ordinary people who have for a long time held illogical prejudices against a group. Because of preconceptions many Americans have reacted antagonistically toward the Jews. But the data presented above offer no support for the idea that the Jews dominate America out of proportion to their numbers. Jews do not appear to an overwhelming extent as leaders in any of the vocational fields and they do not come up to expectations in a number of occupations. Their appearance in finance, law and business may be expected to call unfavorable attention to them, but there are no grounds in any of the data for special emphasis on the quantity or quality of the group's accomplish-

[26] *Cf.* Ludwig Lewisohn, "Upstream," for a vivid example of such discrimination. New York, 1922.

ments. Instead, it should be kept in mind that their contribution is in every case as much an American contribution as those of other Americans. We have no reason to suppose that this group has any more pride in its accomplishments than has any other religious, or any ethnic or language, component of the American population, or that it is more interested in having itself singled out for comment than is true of any other part of the population. Our interest in the contributions of any part of the American population should be purely of historical and academic interest, especially in view of the fact that all religious minorities seem to be equally loyal to the principles on which the nation is founded; and the same is true of all national minorities, except those attached to some aggressive international political and military movement, which, however, in no respect applies to the Jews. Indeed, there is reason to believe that the assimilation of the Jews in this country will proceed until studies of the sort reviewed here will cease to have even an academic interest, if the rest of the American people put no emphasis on religious, nationality and culture differences and cease to discriminate against the Jews.

FATS AND OILS

Not counting petroleum oil and essential oils used in perfumes, there are about 30 fats and oils which form an important part of our peacetime life and are grim necessities in war. War in the Pacific has jeopardized two thirds of the 15 per cent. of these fats and oils we normally import.

Fats and oils are necessary for food, for soap, for paints, varnishes, linoleum and printers' ink, for industrial lubricants, and in the manufacture of metals, textiles, leather goods and glycerine. In times of peace, glycerine, required in the making of nitroglycerine and other explosives, is a by-product of soap-making, but in time of war soap rather becomes a by-product of glycerine manufacture.

Edible fats are highly important foods in wartime because their outstanding caloric value makes them especially needful for the armed forces and for civilians working longer hours and under increased strain. The paint and varnish oils are used increasingly for the protective coating of ships, tanks, guns, planes, cantonments, and so on. Special lubricants are required more than usual for high-speed motors and metal-turning lathes.

In 1940–41 we imported 1.6 billion pounds of fats and oils, including the oil contained in oilseeds, and more than half of these products originated in the Pacific area. The principal items imported from this area were coconut oil and copra, mostly from the Philippines, and palm oil, from the Netherlands Indies and Malaya. Imports of perilla and of tung oils also originated in the Pacific; Japan controls the supplies of the former, while the latter is a Chinese product. Alternative sources of supply for coconut oil and copra were the Netherlands East Indies, and various South Pacific Islands, as well as East Africa, whence we may still derive some. In the past we have also obtained considerable quantities of palm oil from West Africa.

Substitutes for coconut oil are available in the form of babassu and other palm-kernel oils contained in the nuts of certain varieties of palm trees found in great profusion in tropical Latin America. But transport, labor and equipment shortages preclude any rapid expansion of imports of palm-nut kernels to the United States. Fairly large quantities of palm-kernels are available in West Africa. Brazilian oiticica oil and dehydrated castor oil, derived largely from Brazilian castor beans, are already being used to supplement supplies of tung oil and perilla oil in the United States.—*United States Department of Agriculture.*

THE WHALE SHARK IN THE PHILIPPINES

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THROUGHOUT the ages sharks have been of well-nigh universal interest. Lacking the gorgeous colors or flower-life brilliance of coral reef fishes, or the superb symmetry and graceful gyrations of others, they have yet irresistibly compelled the attention of man. Most sharks are dull in color, uniformly gray, bluish or brown, only a small number being decorated or colored in such a way as to attract attention.

While a few sharks, such as the weird hammer-heads, have excited astonishment by their singular physiognomy, other characteristics have been the means of causing mankind to observe and speculate about them. The qualities that have aroused awe and curiosity are uncommon size, speed, great greed and dangerous ferocity. It is the combination of all these in the popular mind that has made the name shark a symbol for all that is fierce, rapacious and ruthless to millions who have never seen one.

It is not of man-eating sharks nor of the living fossils that range the depths nor yet of the pygmy phosphorescent sharks less than a foot long that these observations are recorded. Instead, the subject is a harmless blundering giant, the largest of all living fishes, the titanic whale shark, *Rhineodon typus* Andrew Smith.

One hundred fourteen years ago, in April, 1828, to be exact, a large shark was seen swimming aimlessly at the surface in Table Bay, Cape of Good Hope, South Africa. It was unlike anything known to the local fishermen, and its color was different from that of any shark occurring in those waters. It was easily harpooned and towed ashore. Here it was turned over to Dr. Andrew Smith, an army surgeon. He recognized it at once as something hitherto unknown, and published a description of it. Some years later he published the first, and one of the very best figures ever made of it.

However, long before Dr. Smith's scientific account, Captain H. Piddington, the English commander of a small Spanish brig, saw a *chacon,* or whale shark, in December, 1816, while his vessel was lying at anchor in Mariveles Bay, a small haven near the entrance of Manila Bay. He did not publish his observations until 1835, when his article entitled, "Notice of an Extraordinary Fish," appeared in the *Journal of the Asiatic Society of Bengal.* The *chacon* passed under his ship, moving slowly as is the wont of the whale shark, and he had a good view of it. He estimated its length as "not less than 70 or 80 feet." He was told that formerly there had been two of the monsters, but that about 1800 one was driven ashore, where it died. Captain Piddington's article has been reproduced in full by my friend and scientific colleague, Dr. E. W. Gudger, internationally known ichthyologist of the American Museum of Natural History. Captain Piddington's account is therefore the first authentic record of the occurrence of the whale shark in the Philippines.

In his article Captain Piddington added "a vague notice of monstrous spotted fish, which are known to the Moluccas." The Malay fishermen described them to him as "spotted, as large as a whale and highly destructive to nets, which they instantly take up as soon as they see the fish, if they can get time to do so; for it is known to destroy boats, and whole lines of nets and fishing

stakes, if it once became entangled amongst them."

Continuing his narrative, Piddington says, "I had the same account corroborated in the Sooloo Islands, both by Malay and Chinese fishermen; as also at Zebu, in the Philippine Islands."

There have been no Chinese fishermen in the Sulu Sea for many years, except perhaps a few at the entrance to Sandakan Bay, British North Borneo. By his Malay fishermen in the Sulu Islands, Piddington evidently meant the bold and hardy Samals, erstwhile pirates and always excellent seamen and fishermen. Their knowledge of the fishes of the Sulu and Celebes Seas is both extensive and accurate. We may therefore accept this statement as evidence that the whale shark was well known in the Sulu Sea more than a hundred years ago. What he was told at Cebu agres exactly with our present knowledge of the distribution of the whale shark in Philippine waters.

The whale shark has several characteristics that strikingly differentiate it from all other sharks, large or small. It is usually reddish or grayish brown, or mouse color, with large white or yellowish circular spots the size of a silver dollar or larger, which occur all over the body and fins, except on the under side. On the head the spots are much smaller and more crowded; on the body there are also vertical white or yellowish lines or stripes, running from the back to the belly, which connect the circular spots. These lines may be continuous, but are more often interrupted, thus forming a series of short vertical stripes.

Another very marked characteristic is the presence of two longitudinal keels or ridges on each side, beginning above the fifth gill slit, the upper one soon dividing and terminating near or under the second dorsal fin. The lower one continues on back in a more or less wavy manner until it is lost in the strong keel on either side of the tail. The huge head is very blunt, broad and depressed, with a perfectly enormous mouth, which is at the front instead of being beneath and far behind the snout, as in most sharks.

The immensely wide mouth has a band of about three hundred rows of minute teeth in each jaw, each row containing from fourteen to thirty teeth. The number of teeth varies from about 5,000 to 9,000. The whale shark feeds on very small fish, crustacea, mollusca, medusae and various other pelagic organisms occurring in vast schools at or near the surface of the sea. It feeds in the same manner as ordinary whales do, that is, by swimming slowly with wide-open mouth through schools of the organisms which form its food. After the mouth is filled with sea water and the mass of small animals, it is closed and the water is expelled through the gill openings, which are provided with a fringe of mesh-work that serve as a strain.

The whale shark is one of the mildest and most inoffensive of all large animals. In spite of its enormous size and monstrous strength, it never attacks anything larger than the small animals on which it feeds. When harpooned or shot it makes no particular attempt to escape, nor does it use its great strength to wreck the boat of its enemies. The only exceptions noted during more than fifty years are those recorded by Wright, the naturalist, who observed the shark at the Seychelles. According to him it sometimes rubs itself against a pirogue (dug-out canoe) and consequently upsets it, but never attacks any one. He also states that sometimes when a whale shark is harpooned it dives with very great rapidity until the rope is all out, and then keeps on downward until the boat is carried under before the crew has time to escape.

Accordingly, the sperm whale fishermen were in great dread of mistakenly harpooning a whale shark, instead of a

whale. The latter must return to the surface after a time to breathe, but the fish could go to a vast depth and remain there. However, the statements about carrying boats under water were hearsay, as Wright never saw anything of the kind himself. With the exception of Piddington's original account, all other statements made for over a century, by actual observers, were unanimous in saying that a whale shark when harpooned swims slowly away at a speed of two miles an hour or little more, or else circles aimlessly about at the same slow speed. When Piddington's boatswain and four companions harpooned the "chacon" it towed them "at such a fearful rate out to sea that they were glad to cut from it immediately."

In the last chapter of Zane Grey's "Tales of Fishing Virgin Seas," published in 1925, there is a description of an encounter with a whale shark over fifty feet long off Cape San Lucas, Lower California, where whale sharks are common. The great fish was harpooned and fought from noon till after sunset. During that time it sounded five times, going down to 1,200 feet the fifth time. Finally it sounded for the sixth time. At 1,500 feet the last ball of rope was added and the fish had to be released or it would have taken the boat down, too. There is no question, therefore, that the whale shark does, at times, free itself by going far below.

At intervals during the seventy-two years between 1828 and 1900, various observers reported the whale shark on the coast of Ceylon, in the Gulf of California, around the Seychelles (a group of small islands in the Indian Ocean) near Callao, Peru, in the Bay of Panama, and on the south coast of New Guinea.

With the dawn of the present century, whale sharks began to be noticed in many localities. Such diverse regions as Japan, Celebes, in the Dutch East Indies, Florida, the Hugli River in India, Java, the Bonin Islands, the Strait of Bab-el-Mandeb, the Gulf of Guinea, and many other localities distributed throughout the Pacific, Indian and Atlantic Oceans, were added in rapid succession. Beginning in 1910, the record of whale sharks in Philippine waters is greater than that of any other region, but first a few words concerning the method of their capture.

One of the most important means of fishing throughout Malayan countries is that of constructing fish corrals of one sort or another at strategic points. They are of all sizes, from tiny affairs only large enough to hold a dozen fish or so weighing a pound or two apiece, to gigantic complicated affairs that in one night, or at a favorable turn of the tide, may catch three or four thousand fish, weighing an average of five or six pounds apiece.

These corrals are placed at all depths between those that are exposed on flats at low tide to those that stand where the water is permanently forty-five or fifty feet deep. They may be flimsy fences of reeds and bamboo, costing only the necessary labor, or they may be huge solidly built structures of great hardwood logs, rattan and bamboo, tied together by roots that resist the action of salt water, which cost several thousand dollars.

In the outlet of every lowland lake, at every river mouth and on a coastal sheltered beach or reef anywhere, one sees an array of fish corrals. As the tides change and currents shift, as the monsoon winds blow now this way and now that, the movements of fishes, and indeed of all free natant life, are likewise altered. Into the corrals accordingly there comes a vast variety of fishes and other organisms, and often a great number of a single species when a migrating school is captured, as occurs when a corral is placed across a reef channel regularly used in migrations. Follow-

ing their food of squid, floating mollusca, schools of crustacea or of small fishes frequenting shallow water or perhaps merely traveling with the current, such large animals as blackfish, porpoise, small whales, dugong, saw-fish and whale sharks are led into the pounds of fish corrals. There they remain, except when a gam of blackfish or a school of porpoise is captured. When they once realize that they are imprisoned, they burst all barriers, leaving behind only a wrecked corral.

If one remembers that there are more than 7,000 islands in the Philippines, ranging in size from mere rocks to the size of Ohio, with more than 400 permanently inhabited, it is evident that the Islands have an enormous coast-line. It is on this coast-line that most of the 16,000,000 inhabitants live. With fish corrals scattered along most coasts, there are in the aggregate thousands of fish corrals in operation for at least a large part of every year. With this great number of fish corrals, the chances for capturing strays and rarities of many species are immeasurably increased.

To return to the first capture in 1910, in August a giant shark was discovered in a fish corral at a barrio or village of the municipality of Bacolod, Occidental Negros. After the tide went out, the great fish was partially stranded. It was then killed and dragged by an excited crowd more than two kilometers inland, to Bacolod itself. Here a local photographer took a picture of the shark in the midst of the crowd that was sent to the *Philippine Free Press*, which published it in the September 10, 1910, issue.

During 1914, two whale sharks were captured in the Philippines, and a school of them was observed about that time, but published notices were not made till afterward. Most of the information relating to that period has been obtained from Captain William M. Steirnagle, who was in command of the Coast and Geodetic ship, "Romblon" from 1912 to 1915. During this period surveys were being made of the coasts and reefs of the Philippines. Several years after returning to the States, Captain Steirnagle called on Dr. Gudger and told him of observing whale sharks in the Philippines and of frequently seeing as many as fifty whale sharks in a school. He gave Dr. Gudger several small pictures, one of which shows the exposed head of a shark which is readily recognized as a whale shark by its spots and by the shape of the head.

In *Science*, Vol. 41, p. 463, 1915, Dr. David Starr Jordan published a note concerning a photograph he had received from a former student of a whale shark captured at Cebu, where the former Stanford man had seen it. Since the ex-student lived in Zamboanga, the fish has later been erroneously recorded as having been taken at that place.

In September, 1914, another whale shark, a young one eighteen feet long, was caught in a fish corral at Argao, Cebu, a town on the east coast about forty miles south of the city. An excellent photograph of it was taken by an American friend of mine, who later gave me a copy. This shark was not put on record until January, 1925, when I published an account of the whale shark in the *Philippine Journal of Science*, Vol. 26, pp. 116–117.

While I was in Zamboanga in 1920, an American friend gave me a copy of a picture he had taken of a whale shark caught a few months before in a fish trap near Zamboanga. Soon I sent the picture to Dr. David Starr Jordan, who acknowledged its receipt but never published anything about it.

Early in 1921 while overhauling and naming the fish collection in the museum of Santo Tomas University, Manila, I found on display a stuffed and unnamed whale shark. It was another baby fish, only thirteen feet and nine inches long,

next to the smallest specimen on record. The taxidermist and curator was an elderly Filipino who had spent practically all his life in the museum, his father having been taxidermist before him. He told me that the whale shark was taken in 1840, in Manila Bay off Navotas, by fishermen of that town. He further stated that his father, a boy of eighteen at the time, had helped prepare the skin, but did not remember anything about the manner of its capture. Although the old skin was badly battered and showed hard usage, it had evidently been mounted while in perfect condition, but time and reckless students had done their worst. When the university was moved to the northeastern part of Manila the shark disappeared. In my 1925 article, previously cited, I mentioned this 1840 Navotas specimen.

In January, 1925, while I was absent in Mindanao, word came to the Bureau of Science that a whale had been caught in a fish corral at Salinas, a village near Cavite, the well-known naval station on Manila Bay. Several of the staff went to Salinas and found a whale shark that had blundered into a fish corral at high tide and which was stranded at low tide. It died the next day, at which time pictures were taken by the Bureau photographer, and it was measured. It was thirty-three feet in length, the largest whale shark ever handled in the Philippines by scientific men, but the other measurements made are not now accessible. The owners employed a Manila taxidermist who prepared it for exhibition and for a year or two it was shown at carnivals and fairs.

January, 1925, was a good month for whale sharks. My first assistant, Mr. H. R. Montalban, leaving Lanao about the tenth of the month for Manila, stopped at Dapitan, a town at the northwest angle of Mindanao. From the deck of the steamer he saw a whale shark swimming slowly at the surface of the sea and obtained a very good view of the characteristic spots and shape of the head. A number of other passengers saw the shark and several fired shots at it from revolvers.

The tenth recorded specimen, reported to be nineteen feet long, was taken in 1929 at the barrio of Garat near Libagon, a town on the east side of Sogod Bay at the south end of Leyte. It was reported to be nineteen feet long. The photograph taken of it shows admirably the characteristic wide depressed truncated head.

In September of the same year another whale shark wandered into a fish corral at Cebu, the capital of Cebu. This fish was approximately sixteen feet, five inches long. Again a young *Rhineodon typus* swam into a fish corral, this time at the village of San Vicente, a barrio of Malitbog, a town on the west side of Sogod Bay, Leyte. Malitbog is about ten miles southwest of Libagon on the opposite side of the bay, where a whale shark had been taken six months before. In February the whale shark was hauled out on the beach and a fair picture, taken by a local photographer, indicates that the fish was more than twenty feet long.

Two whale sharks were seen in 1931, the first in February by Mr. A. D. Lee, at that time in charge of fishing operation for the Philippine Packing Corporation in Iligan Bay on the north coast of Mindanao; the second, three months later, was caught in a fish corral at Maasin, a municipality on the southwest coast of Leyte. No data are available as to its length, but it was apparently about 20 feet long judging from a photograph of the crowd of men and boys around it.

On the fourth of August, 1931, I saw a whale shark on the coast of Darvel Bay, British North Borneo, and later (April 15, 1932) published a note about it in *Science*. This record might without much stretching be reckoned in

Philippine waters, since the locality is only about 15 miles from the north end of Sibutu, an island of the Sulu Archipelago.

On January 7, 1932, Navotas fishermen, finding a young whale shark in a fish corral, hauled it out, and pictures of it lying on the beach were taken with a small camera. It was apparently between eighteen and twenty feet in length. In March still another small whale shark entered a fish trap, this time at Aplaya, a barrio in the municipality of Bauan, Batangas Province, Luzon. Bauan is directly south of Manila, on Batangas Bay, an indentation of Verde Passage. This specimen was only seventeen feet and four inches in length.

Later in the year Mr. A. D. Lee again reported seeing many whale sharks. On the first of June, while cruising in Dapitan Bay just southwest of Tagolo Point at the northwest corner of Mindanao, he encountered a school containing fifteen or more whale sharks, ranging in length from twenty to more than fifty feet. Mr. Lee reported that the vessel was fifty feet long and that some of the sharks alongside were even longer. He actually counted fifteen fish, after which he was too busy steering away from the school lest one of the fish come up under the launch and capsize it. On three separate occasions Mr. Lee and his companions saw a school of whale sharks, probably the same school each time, in the region about Tagolo Point.

In February, 1933, a young whale shark was caught in a fish corral at San Jose, Antique Province, Panay. The local fishermen, thinking that it was a man-eater, were afraid to attack it. After several days, Captain Flores, of the local constabulary, went to the corral and with his service rifle wounded the shark, which then broke through the corral. It was pursued in a boat and finally killed. When dragged out on the playa, it was found to be about eighteen feet long. An account of the capture and killing of this whale shark was published in the *Philippine Free Press* on February 25, 1933.

On an afternoon in April, 1934, Dr. Paul Smith, of the United States Quarantine Service at Manila, was fishing near Mariveles, a small town on a landlocked harbor at the north entrance to Manila Bay. For some time he observed a large shark which was approached and finally harpooned. After roping it securely, the fish was towed to Manila, where it died the next morning. This whale shark, only thirteen feet in length, is the smallest one captured of which there is any record, so far as I am aware. Its skin was mounted and is now on exhibition in the Bureau of Science Aquarium at the entrance to the walled city of Manila.

Fishermen at Silay, Occidental Negros, reported to Mr. Florencio Talavera, of the Division of Fisheries, Bureau of Science, a large fish which they had captured in a corral. It was clear to Mr. Talavera that this fish, which was about thirty-nine feet long, was a whale shark. This capture was probably made in 1934, but the date is uncertain.

Mr. Wallace Adams, for a time head of the fish and game administration in the Philippines, had records of other captures of whale sharks in the Islands, and had indicated the localities on a small map. When I saw Mr. Adams in San Francisco and discussed with him the occurrence of whale sharks in the Philippines, he was fatally ill and unable to get at his notes. Shortly after, while I was abroad, his death occurred and his miscellaneous papers were apparently destroyed after his library was sold. All these records, including the one at Silay, Occidental Negros, cited above, were between 1930 and 1934.

He told me he had data of the taking of whale sharks at these places: the Gulf of Albay, Albay Province, Luzon;

Maqueda Bay, Samar; the Tapiantana Islands off the south coast of Basilan, a large island near Zamboanga; and Balabac Strait, Balabac. Including the above, we have twenty-four definite records of the occurrence of whale sharks in the Philippines. His untimely death and the destruction of his papers have prevented my getting more precise data.

In addition to these definite records, it is commonly stated by the market vendors of Cebu, Iloilo, Zamboanga, Jolo and Siasi that young whale sharks are brought in from time to time, cut up and sold for food. I am likewise confident that any one familiar with Philippine people and conditions could gather at least twenty more good records in a few months' time. Many times when investigating the distribution of some fish I have obtained the needed information very readily. By descriptions and pencil sketches fishermen would tell me of the various fishes caught or known to them, their habits, mode of capture and local name. Where their descriptions were too vague, their drawings, supplemented by answers to a few judicious questions, would usually enable me to determine the larger fishes known to them with certainty.

The great apparent increase in whale sharks in recent years is not a real increase. The greater number now reported is merely because the recent rapid development of transportation and communication by automobile, bus, steamer, telephone and wireless enables one to hear of events from the multitude of places that only a few years ago were almost totally isolated from the rest of the world. Formerly communication was so infrequent and irregular that even major events like typhoons and destructive earthquakes might not be made known to the outside for at least six months.

The fact that nearly all Philippine whale sharks captured are small, there being but two records of specimens ten meters or more in length, points to two conclusions. First, a breeding ground must be in some locality at no great distance; second, adult whale sharks remain in deep water, rarely venturing into the shallow coastal waters where fish corrals are located.

My eminent colleague, Dr. E. W. Gudger, believes that the Sulu Sea is the chief breeding ground and center of distribution for the whale shark. From long familiarity with the ocean currents about the Philippines, and with the Sulu Sea in particular, I am inclined to doubt this conclusion. The Sulu Sea is a rather small Mediterranean, perhaps 300 by 350 miles if we exclude small island groups and reefs. It is out of the path of main ocean currents, and except for an inlet through the somewhat tortuous straits of Surigao is margined by channels less than five hundred feet deep. The Sibutu Passage has a maximum depth of 3,000 feet, but north of it lies a shallow reef. The Sulu Sea lies in the monsoon belt, and during the northeast monsoon pours a vast stream into the Sea of Celebes, drawing upon the China Sea to maintain its volume of water. During the southwest monsoon the current in the Sibutu Passage is reversed and the Sulu Sea pours its surplus out through Balabac Strait and the channels northward through the Visayas to the China Sea. This in turn creates an eastward current through the Balintang Channel; what effect it has upon Bashi Channel I can not say. Such currents are of much distributional value locally, but are of no import in wide-spread distribution. We may dismiss a sea of seasonal and constantly shifting or reversing currents as one that can not meet the requirements.

The Celebes Sea is a partial Mediterranean of more than twice the area of the Sulu Sea, and is much more influenced by great oceanic currents. It ap-

parently fits the requirements better than the Sulu Sea in all respects, except in the known occurrence of whale sharks. Its great depth and the scant population along its shores would make it improbable that many whale sharks would be captured there.

There is another area which seems to meet all requirements to a far greater degree than either the Celebes or Sulu Seas. This is the region north of New Guinea and partially enclosed by the Philippines, Halmahera and the Pelew Islands. This area receives both the south and the north equatorial currents, and gives rise to the Japan Current, or Kuro Siwo. In the maze of islands between New Guinea and Celebes there is a welter of criss-cross currents into and out of this area, and from it pours a vast volume of water through the Straits of Surigao in the mid-Philippines. This influx of water from the open Pacific and the Sea of Celebes causes an outflow northward through the Visayas during a large part of the year.

From the movements of albacore, tuna, swordfish and sailfish, we infer that they have a breeding ground in the great area above indicated. From it they migrate westward and northward, reaching first the Sulu Islands and Mindanao, then the Visayas, then Luzon as the season advances, and ultimately travel on toward southern Japan. This route of migration seems to be along the equatorial current and its ramifying distributaries, and along the Kuro Siwo and its offshoots entering the Philippines.

Of course, what is true for these great bony fishes may not be true at all for giant selachians, which in all probability produce living young. We have no evidence that sharks of that type have any specific breeding ground, except that of the occurrence of young sharks in a given region. In spite of our lack of positive knowledge of the breeding habits of *Rhineodon typus,* I am of the opinion that the most important breeding ground, or center of life, for western Pacific whale sharks is the region already indicated, lying between New Guinea and the Philippines. It fulfils all the necessary requirements: water of a uniform high temperature, an abundant food supply of pelagic macroplanktonic organisms, constant ocean currents and a vast undisturbed and seldom visited area, remote from steamship routes.

If my suspicion that whale sharks are largely surface feeders is true, the Sulu Sea is much too frequented by men to have very many unobserved schools of whale sharks in its limited area. Commercial steamer routes traverse the Sulu Sea so frequently that it is under observation throughout the year over a large part of its surface. On the unfrequented waters of the New Guinea-Philippine sector of the Pacific, ships are a rarity.

It is evident that whale sharks breed somewhere in the Indian Ocean, having the area about the Seychelles as their center, but probably breeding in other localities as well. Dr. Gudger's explanation of the distribution of the whale shark in the Indian Ocean and in the tropical Atlantic seems to accord perfectly with all the known facts. However, this does not necessarily imply that in any given sea the breeding of whale sharks is confined to any definite and limited area. It merely gives a reasonable explanation of their distribution from their original home somewhere in the East Indian region.

ANCIENT MESOPOTAMIA AND THE BEGINNINGS OF SCIENCE

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LATEST advances in the study of comparative archeology bring out with added emphasis the traditional view that the oldest historic civilizations evolved in Egypt and Mesopotamia. We know also that intellectual and social progress in these two centers kept pace with material developments. The question of relative priority is often injected into discussions on this subject. For the present, at least, such a question is not capable of a satisfactory solution. It is doubtful, moreover, whether an answer can be expected at all, in view of the dynamic character of both civilizations and the consequent rapid diffusion of vital innovations and inventions. There are, however, certain characteristic aspects of progress in the two respective centers which stand out by contrast, and it is to one particular group of such contrasted characteristics that I wish to address myself here. I am referring to progress in science.

The following remarks will embody four main propositions: (1) Available evidence points to Mesopotamia as the oldest known center of scientific observation permanently recorded. (2) Whatever its immediate objectives, this activity comes to include such widely separated fields as education and language study, jurisprudence and the mathematical and natural sciences. (3) The numerous elements in this broad advance are basically interrelated. The common underlying factor to which the initial impetus can be traced is a concept of society whereby the powers of the state are restricted and the rights of the individual receive a corresponding emphasis. (4) It is significant that under the opposed social system of totalitarian Egypt early scientific development differed in scope as well as in degree; while notable in some special fields, such as medicine and engineering, it lacked the breadth and balance manifested in contemporary Mesopotamia.

It should be pointed out at the outset that the specifically scientific content of this account is negligible; furthermore, it is but incidental and wholly derivative. My main objective is to demonstrate that there were elements in the social structure of early Mesopotamia which tended to promote scientific progress. The results happen to constitute the first recorded evidence of scientific performance known to us to-day. To this extent we are justified in touching here upon the beginnings of science, including the natural sciences. But it should be stressed that this presentation is concerned not so much with the results as with the background: a combination of circumstances conducive to concerted scientific activity, rather than the subjects affected by that activity. The background gives us in this instance the essential starting point. It is thus more significant than the immediate achievement.

Our interest, then, will center on a particular cultural stage at which there were at work forces that led to extensive scientific developments; forces which provided the predisposition, so to speak, to these developments. Accordingly, we shall ignore such sporadic achievements of a still more remote age as the invention of the wheel, the introduction of the brick-mold, and perhaps the use of instruments in effecting accurate geo-

metric designs on very early forms of painted pottery. We may have here Mesopotamian inventions which were to play important parts in the eventual progress of engineering, architecture and perhaps geometry. But these inventions represent isolated contributions of discontinuous cultures which scarcely had any immediate bearing on scientific progress. We shall confine ourselves to subjects which had a common origin in a well-defined period and area; which involve from the start habits of observation, classification and analysis; and which enter then and there upon a continuous course of development.

The region to which our inquiry will take us is Lower Mesopotamia, the land of Ancient Sumer. More specifically, it is an area extending southwest from the environs of Babylon, past Uruk—the biblical Erech—and on along the Euphrates to the metropolis of Ur. The time is the middle of the fourth millennium B.C. This is not just a convenient round figure. It will allow a margin of scarcely more than a century or two, and in a total of well over five thousand years this is not a disproportionate margin of error. We are in a position to establish the time with such accuracy because it falls within a well-stratified cultural period marked off sharply by distinctive material remains. Soon thereafter there begin to appear inscribed records which tie up before long with concrete regnal years and provide thus a basis for absolute chronology.

We get our first inscribed documents from a level dated to about 3500 B.C., one of a long series of strata recovered from the remains of ancient Uruk. It is among these documents, written on clay, that we find a few which represent the earliest known scientific records. That similar records of still greater antiquity will ever turn up outside Mesopotamia is highly improbable. All available evidence points to the conclusion that the scientific notations with which we are concerned were compiled in close association with the introduction of writing itself. To be sure, this evidence applies only to the script of Mesopotamia. But writing in all the other ancient centers of civilization is demonstrably later. In Egypt it was introduced some centuries after it had been evolved in Mesopotamia, and its first appearance in India was later still. As for the script of China, there is nothing to indicate that it was earlier than the second millennium B.C. It follows, therefore, that the scientific notations on our earliest Mesopotamian tablets constitute not only the first evidence of scientific activity in Sumer, but represent also the oldest recorded effort of this kind known from anywhere in the world. With this significant fact in mind we shall now turn briefly to the records themselves.

What is it that would justify the use of the term "scientific" as applied to a few of the oldest inscribed documents from Mesopotamia? The answer is bound up with the character and purpose of these special texts. Each of them contains lists of related entries. But these lists have nothing in common with the customary inventories of a strictly economic nature. They serve an intellectual rather than a material purpose. And yet, they are to enjoy a continuity and distribution which will set them off sharply from the usual run of business documents whose significance is at once temporary and local. The lists in question are destined to be copied and recopied for many centuries and in more than one city and country. Actual examples of such copies, often modified and expanded, but still in a clear line of descent from the oldest prototypes, have been discovered in Mesopotamian sites of much later age, and even in foreign capitals like Elamite Susa. We have thus before us the beginning of a family of documents of a scholarly char-

acter which are notable for their continuity, distribution and purposeful adherence to an established tradition.[1]

In this recording of accumulating experience and the manifest applicability of such records to the needs of cultural centers separated by political, linguistic and chronological barriers we have the essential ingredients of scientific performance. Now what science or sciences did this activity embrace? We shall see presently that the primary purpose of the lists under discussion was to aid in the preservation of the knowledge of writing. Before long, philological studies become an added objective, owing largely to the composite ethnic and linguistic background of early historic Mesopotamia. But natural sciences, too, soon come in for their share of attention.

For regardless of the primary purpose of our lists, they happen to include quite early in their history groupings of birds, fish, domestic animals, plants, and the like. It is worth stressing that these compilations presuppose careful observation and imply organization and analysis of the accumulated data.[2] As an element in the cumulative tradition of the land the lists are subject to steady expansion and improvement. What is more, although these texts were calculated originally to serve purposes unrelated to their subject-matter, they led in course of time to the independent study of the subject-matter involved. The fields affected are zoology and botany, and later on geology and chemistry. The first recognition of all these subjects as so many separate fields of study may be traced back, therefore, to the earliest inscribed documents from Mesopotamia. Interestingly enough, that recognition was due ultimately to the fact that man had just discovered in writing a way to arrest time and was applying all his ingenuity to the task of keeping this discovery alive.

The subsequent progress of the individual sciences just mentioned has to be traced by specialists. We are concerned at present with the initial impetus alone, and the time and circumstances in which that impetus was first received. A few details, however, may be brought out in passing. In the light of the foregoing remarks botanists will not be surprised to learn that many of the terms which they use to-day are found in Mesopotamian sources. These terms include "cassia" (cuneiform *kasû*), "chicory" (*kukru*), "cumin" (*kamûnu*), "crocus" (*kurkânû*), "hyssop" (*zûpu*), "myrrh" (*murru*), "nard" (*lardu*), "saffron" (*azupirânîtu*), and probably many others. The zoological compilations which are accessible in cuneiform records contains hundreds of names systematically arranged and presented in two columns, the first giving the Sumerian term and the other its Akkadian equivalent.[3] The scholastic tradition in chemistry[4] results in such texts as the one which has come down to us from the second millennium B.C., wherein a formula for glazing pottery is preserved in the guise of a cryptogram so as to remain hidden from the uninitiated.[5] The importance of the natural sciences for the study of medicine is self-evident; it was not lost on Babylonian and Assyrian medicine.

So much for the indirect benefits derived from the lists under discussion.

[1] These facts are brought out clearly by A. Falkenstein, whose "Archaische Texte aus Uruk" (Berlin, 1936) is the basic work on the earliest documents from Mesopotamia; *cf.* especially pp. 43 *ff.*

[2] Careful observation is evidenced also by the accurate drawings of the early pictographs, particularly where exotic animals and specific plants were concerned.

[3] See Benno Landsberger (in cooperation with I. Krumbiegel), "Die Fauna des alten Mesopotamien" (Leipzig, 1934).

[4] On this subject *cf.* R. Campbell Thompson, "A Dictionary of Assyrian Chemistry and Geology" (Oxford, 1936).

[5] R. Campbell Thompson and C. J. Gadd, in "Iraq," III (1936), pp. 87 *ff.*

But the primary objective of these compilations was not allowed to suffer in the meantime. On the contrary, the direct results which were achieved with their aid led to an immensely fruitful advance in another field of intellectual progress.

It was stated above that our lists were intended as a means to preserve the newly attained knowledge of script. By the very nature of its origin in concrete pictographs early writing was an elaborate medium consisting of thousands of items. To each new prospective user it represented a code which could not be deciphered without a proper key. The lists were calculated to supply that key. They were analytical catalogues of signs arranged according to form. Inasmuch as each sign was at first a reflection of something specific in the material world, these catalogues were at the same time systematic groupings of related objects; hence their incidental value to the natural sciences, as we have just seen. The immediate purpose, however, of these arrangements was pedagogical; they are our oldest manuals for the discipline of education. As pictographs and ideograms gradually took on abstract phonetic values, the study of the script became linked perforce with the study of language. After the Semitic-speaking Akkadians had joined the Sumerians in building up the civilization of Mesopotamia, linguistic studies rose to exceptional heights against this bilingual background.

The deep-rooted respect for scholarly tradition which comes with a sense of dependence on the contributions of the past, implicit in the developments here outlined, had much to do with the unparalleled achievements of ancient Mesopotamia in the field of linguistics. For it meant that the Akkadians, Babylonians and Assyrians must fall back upon records in the unrelated tongue of Sumer. The knowledge of that language had to be maintained for cultural purposes long after its speakers had lost all political power, even after they had disappeared from the scene altogether. For the first time in history translators are at work to commit their renderings to writing. This activity called for the production of various auxiliary manuals: syllabaries giving the phonetic value, form and name of each given sign; vocabularies containing the Sumerian pronunciation, ideogram and Akkadian equivalent of each word or group of words; lists of synonyms, commentaries on selected ideograms, interlinear transliterations with given Sumerian texts, and the like. Nor was this all. The scientific analysis of Sumerian took the form of grammatical works arranged in paradigms according to the parts of speech and explicit down to such minutiae as the place of the accent. Differences in the dialects of Sumerian were carefully noted. And most of this formidable apparatus was available and in use four thousand years ago! It is to this apparatus that we owe our present knowledge not only of the various dialects of Sumerian and Akkadian, but also of such languages as Elamite, Hittite, Hurrian and Urartian. As linguistic material these languages may be of interest only to a small group of specialists. But as the media for expressing the thought of a large portion of the ancient world over a period of three millennia—a period one and a half times as long as the whole of the present era—they have a deep significance for the entire civilized world.

The foregoing outline has had as its main theme the demonstration that many forms of scientific progress in Mesopotamia were influenced and linked together by a scholarly tradition which was in turn the by-product of the invention of writing. Our survey has failed, however, thus far to include mathematics and astronomy, two fields for which Mesopotamia has long been celebrated,

and is so now more than ever owing to the researches of Professor Neugebauer. It goes without saying that these subjects were affected no less than the other disciplines by the same forces which made for a broad cultural advance in general. But the primary cause of the extraordinary development of mathematical and related studies in Mesopotamia is to be sought, I believe, in conditions which antedate the introduction of writing. In fact, I would add, the origin of writing as well as the interest in mathematics are to be traced back, in this case, to a common source. This source will be found inherent in the society and economy of the prehistoric Sumerians.

We know to-day that the Sumerians got their idea of writing from the cylinder seals which they engraved with various designs to serve as personal symbols. These symbols came to be employed as marks of identification for religious and economic purposes, for example, with temple offerings. In this representational function the old designs develop into concrete graphs for humans, animals, plants, and so forth, and thence for temples, gods and cities. The graphs are then associated in each instance with specific words. The gap between picture and word is bridged. Gradually means are devised to express not only complete words but also component syllables, the advance leading thus from the concrete to the abstract. At length writing is perfected to function as a flexible medium for the recording of speech and thought.

When we look back now on the successive interlocking stages in this complicated process, which has been sketched here in its barest outlines, an interesting fact will emerge. The early Sumerians had not set out at all to invent writing. They were led to this result by a combination of peculiar circumstances. The outcome had scarcely been planned or foreseen. The achievement of the discoverers lay chiefly in their ability to recognize and seize their opportunity. This they did with truly remarkable ingenuity and perseverance. That they had the opportunity to begin with was due, however, to the way in which their society functioned. This system can now be reconstructed from a wealth of diversified evidence. Only a rough summary can be attempted at present.

We have seen that the immediate ancestor of Mesopotamian writing was the cylinder seal which was first and foremost the Sumerian's mark of ownership. Impressed on clay or cloth it served to safeguard in the eyes of god and man one's title to possessions or merchandise. We have here a clear indication of a strongly developed sense of private property and thereby of individual rights and individual initiative.[6] The curious shape of the cylinder seal, original with the Sumerians, is explained by its use as a mark of individual ownership. For such cylindrical objects are well suited to cover uneven surfaces with their distinctive design.[7]

Wholly consistent with this economic origin of writing is the fact that the earliest written documents are given over to temple economy. Later texts branch out into the field of private business. Both these uses testify independently to the importance attaching to property rights. Records of a non-economic character are the last to appear, except for the lists discussed above which served as direct aids to writing. The first inscribed documents were used, accordingly, for economic ends, precisely as the cylinder seals themselves. It is easy to understand why the oldest pictographs were so often identical with the designs on the seals.

It follows that Mesopotamian writing,

[6] *Cf.* E. A. Speiser, *Supplement* to the *Journal of the American Oriental Society*, No. 4 (Vol. 59, 1939), pp. 17 *ff.* (esp. pp. 25–28).

[7] See H. Frankfort, "Cylinder Seals" (London, 1939), p. 2.

and hence the first script known to man, was the unforeseen outgrowth of a social order which was founded on a recognition of personal rights. This basic feature of Sumerian society is attested overwhelmingly in cuneiform law, perhaps the most characteristic and the most abundant expression of ancient Mesopotamian civilization. In the last analysis this law rests on individual rights. It is not surprising, therefore, that proof of ownership becomes a vital necessity under this system. Incidentally, the rigid requirement of such proof is the main reason for the hundreds of thousands of legal documents recovered from the buried sites of Mesopotamia; the forces responsible for the introduction of writing continued thus as the primary factor in the subsequent popularity of script. The law applies to ruler and subjects alike. The king is at first no more than a "great man," as is shown by the Sumerian etymology of the term as well as the form of the corresponding pictograph. He may become the administrator of a vast empire, but even then he is still the servant, not the source of the law, and is responsible to the gods for its enactment. There is here no encouragement of absolute power. Law codes are the constitution which guides the ruler and safeguards the subjects. We have seen that this system is capable of promoting cultural progress on an extensive scale. Its inherent vitality is evidenced by the ease with which this order maintains itself for thousands of years in spite of a succession of political changes under the Sumerians, Akkadians, Gutians, Babylonians, Kassites and Assyrians. Nor is further expansion hindered by ethnic or linguistic obstacles in its path; for distant and heterogeneous outsiders are attracted not infrequently to the orbit of the Mesopotamian civilization. Among the newcomers we find the Elamites, the Hurrians and the Hittites, the last-named a people of European ancestry and Indo-European speech. Incidentally, it is to the influence of Mesopotamia upon the Hittites that we owe to-day our oldest available records of any Indo-European language. The newcomers proceed to copy the laws, use the script and enjoy the other benefits of the adopted civilization.

Enough has been said to imply that mathematics and time-reckoning were bound to prosper against this social and economic background. An obvious corollary is preoccupation with metrology, with the result that Mesopotamian weights and measures spread eventually beyond the domain of the parent culture. But the technical features of these disciplines do not lie within the scope of the present account.[8]

To sum up, there existed an intimate relation between scientific progress in Mesopotamia and the source of historic Mesopotamian civilization. Underlying all was a social order resting on the rights of the individual, embodied in a competitive economy, and protected by the supreme authority of the law. This system brought about the evolution of writing, henceforward a decisive factor in the advance of civilization and its diffusion across the changing ethnic and political boundaries. We have here the essentials of a truly cosmopolitan civilization notable for its assimilatory power and a science broad in scope and balanced through the inner unity of its many branches.

Would this story of scientific development have differed appreciably under another type of civilization? The answer is hinted in one of history's most magnificent experiments. The one center possessing a culture of comparable antiquity but dissimilar social and economic background was Egypt. Here the king was a god and as such the absolute ruler and titular owner of all that his realm contained. Under this concept of

[8] Note the article by V. Gordon Childe, on "The Oriental Background of European Science," *The Modern Quarterly* I, Number 2 (1938), pp. 105 *ff*.

government there was no room for the recognition of private ownership of property and the all-embracing power of the law. The pharaoh was dictator of a state genuinely and thoroughly totalitarian. The pyramids bear lasting and eloquent testimony to his enormous authority.

We are not concerned here with the respective merits of two contracting forms of government. Our interest is confined for the present to the effect of coexistent civilizations upon the progress of science in the two centers under comparison. The perspective of more than five thousand years can not but deepen our appreciation of the debt which modern life owes to both Egypt and Mesopotamia. By the same token, however, we are able now to view objectively some of the differences between their respective achievements.

The established superiority of Mesopotamian mathematics may be attributed, in part at least, to the stimulus of the local economy, so different from the Egyptian. Opposed concepts of property ownership and the fundamental rights of the individual were responsible for the intensive pursuit of legal studies in the one instance and their subsidiary role in the other. The astounding accomplishment of Mesopotamia in the field of linguistics had no adequate counterpart in Egypt. Now we have seen that in Mesopotamia progress in linguistic studies, not to cite now other branches of science, was linked intimately with the development of writing. But was not Egyptian writing a correspondingly potent factor?

If this question can not be answered with complete confidence it is largely because the origin of the Egyptian form of script is still open to conjecture. Some details, however, are certain and beyond dispute. The earliest inscribed records of Egypt are some centuries later than the first written documents of Mesopotamia. In Sumer we can follow the successive paleographic stages step by step, whereas in Egypt the formative period of writing seems to have been very short indeed, to judge from the available material. Moreover, writing left in Sumer a clearly marked trail which leads back to a specific social and economic set-up; in Egypt there is no such demonstrable relationship. Because of all these facts, and in view also of commercial and cultural links known to have connected Egypt and Mesopotamia at the very period under discussion, it is logical to assume that Egypt imported the idea of writing from Mesopotamia. Differences in the form and use of the signs would correspond, then, to the existing differences in the art and languages of the two cultural centers. On present evidence, any other assumption would leave far too much to coincidence.[9] In the final analysis it is not so much a question of the mere use of script as of the conditions responsible for the original emergence of writing.

At all events, Egyptian writing, regardless of its origin, inevitably played its part in the notable progress of Egyptian science. What we miss here, however, is the scope and inner unity of scientific advance which we found to be so characteristic of Mesopotamia. That unity was the product of a tradition which is traceable ultimately to a particular concept of life. In totalitarian Egypt a different set of values attached to life and government and tradition. Is this the reason for an effort that seems more sporadic, greater perhaps in its power of concentration on specific objectives, but also more conspicuous for its omissions? Over a period of millennia this appears to be a justifiable comparative appraisal of the results achieved in the field of science by the two oldest historic civilizations.

[9] *Cf.* Speiser, *op. cit.* 22, note 12, and Siegfried Schott, in Kurt Sethe's "Vom Bilde zum Buchstaben" (1939) pp. 81 *ff*.

THE RELATION OF ETHICS TO HUMAN PROGRESS

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Ethics Derived from the Laws of Nature

The actions of every living being are guided by its search for happiness. Prudence, sagacity, discretion, shrewdness, sympathy, judgment and at last wisdom govern the conduct of life in successively higher stages, but through all these there runs the constant thread of striving to be happy. More than any other factor, the desire for happiness is the motive power of evolution.

During the centuries of recorded history, men have repeatedly developed new principles of conduct, such as the Ten Commandments of Moses, the teachings of the church, and national or party doctrine; but the pressure of events has forced continual change. Under new conditions the old rules no longer provide the accustomed benefits, unhappiness ensues, and revolutions follow closely, yielding in turn new codes of ethics. As time goes on, these codes deal more and more with social objectives and group behavior, going far beyond the personal morality of our ancestors. Now, more than ever before, men feel a need for principles of right conduct, attuned to changing conditions, and based on reason rather than tradition. Certain it is that the day has gone by for general adherence to static rules of conduct laid down by any authority.

In my own experience as an engineer, I have been continually impressed by analogies between the recorded progress of evolution, the processes of growth, and the phenomena of fluid flow, all of which proceed in accordance with inexorable natural laws. There surely must be, therefore, some general principles of ethics which can be derived from observations of nature; just as we have derived the laws of geometry and of motion. Such ethical principles must bear a close relation to the laws of survival which underlie the processes of organic evolution, and ought to be more useful in guiding human affairs than pronouncements from dictators of whatever sort.

The engineer's philosophy, or correlation of ethics with evolution, that has grown out of this process of observation and study is briefly summed up in seven statements, or theses:

(1) Right conduct consists essentially in promoting the progress of evolution; that is, living in harmony with the laws of nature.

(2) Evolution consists in the development of more numerous, more varied, more specialized, and more highly organized living types, existing at higher comfort levels; or, in a few words, the creation of greater happiness for greater numbers.

(3) The twin measures of progress in evolution, therefore, are the progress of engineering, or the beneficent control of nature by man, and the degree of happiness existing.

(4) The best assurance of individual happiness is the free exercise of all one's abilities.

(5) The best assurance of engineering progress is the free exercise of all human abilities, with that balance between individual and collective efforts best suited to the existing state of evolution.

(6) Both group and individual abilities are greatest when specialization is effected, as permitted by the cooperation

resulting from sympathetic understanding.

(7) These abilities are most freely exercised when human society is stable, but not stagnant, as occurs when honesty is the rule of living.

The precepts of the natural ethics thus derived from observations on human evolution stress the positive virtues of productive activity, cooperation and honesty, on the pragmatic grounds that they promote progress; rather than the negative virtues of abstinence, meekness, thrift and charity, which have received traditional emphasis. The conclusions reached are not especially new, but they offer a basis for more logical and practical morality than purely authoritarian precepts.

The Nature of Right Conduct

How to tell right from wrong is a problem of age-old difficulty, which must largely be answered by each individual on the basis of his own experience. In the animal kingdom, ethics rarely transcends the level of "sauve qui peut," but men must weigh the rights of others against their own, and the present against the future.

In modern business, knotty ethical questions are continually arising, which demand the highest wisdom for their just solution. Two examples from the experience of an old contractor may not be amiss in this connection. In bidding on alterations to a church, he met severe price competition, but felt that he could not afford to reduce future price levels by publicly reducing his bid. On the other hand, he felt that for his men's sake he must secure the job, even at a loss to himself. He, therefore, privately donated to the church funds a sum equal to the expected margin above bare costs, and so was awarded the contract. Did he, or the church authorities, or both, do wrong in this case? At another time, he was awarded a large contract on the basis of a low bid, but soon found that he had greatly underestimated the cost of the work. Instead of trying to evade the contract, or skimping it, he carried it through in the best manner, and then made a frank statement to his employers of the amount by which the cost exceeded his bid. They were so well impressed that they awarded him the additional amount. Here, certainly, was sound morality on both sides.

Up to a century ago, most philosophers based their ethical theories on divine revelations, or metaphysical assumptions, and then proceeded to judge historical events and human actions as right or wrong according as they did or did not agree with these arbitrary principles. After Darwin and Spencer, however, the tendency has been to take survival as a chief criterion of right. Who will assert that the extinction of the dinosaurs and the rise of the human race were morally wrong, and how do these facts of survival differ in ethical value from the submergence of the American Indian by the tide of white civilization?

The principles of evolution govern the survival of the fittest groups, and not merely the fittest individuals. Actions that have a maximum survival value evidently create maximum activity and expansion, or general well-being, and, therefore, they promote happiness of the group in question. It appears, therefore, that the development of sympathy and other altruistic motives has come about as naturally in the evolution of group abilities through specialization and cooperation, as the development of egoistic motives came about in the earlier evolution of individual abilities. Thus, all human motives have been concomitants of progress in civilization, and the ethical principles of right and wrong must be determinable from the direction taken by human progress.

Our basic inquiry must be, What is the purpose of our existence? Well, viewed from the present day, the only tangible object of the existence of Nean-

derthal man and his contemporaries was surely to produce ourselves. So, from a cosmic view-point, and excluding the possibilities of life after death, we exist to carry on in the development of our ultimate descendants. The production of material objects, transitory and non-perpetuating as they are, can not be considered an object of human existence. Nature proceeds slowly, but inexorably, and this process of organic evolution that has produced us from primitive ancestors will continue in the future, as surely as night will continue to alternate with day. The purpose of our existence is to progress in the train of evolution toward an unknown goal, which can not be foreseen, and which it is futile to imagine. All we can do is to proceed as rapidly as possible along the tangent to the curve of world evolution, as closely as we can determine its direction.

If the purpose of our existence is known, the question of right and wrong is settled. It is right to further that purpose, and wrong to oppose it. It may be suggested that man is being relentlessly carried along in the stream of evolution, and that it is his duty to struggle against it with all his might, hoping finally to hold his own, or even to turn time backward in its flight. Such a theory is untenable, however, as contrary to all our experience of good and evil results from human actions. When we foresee the coming storm and take shelter in time, we avoid destruction; when we plant with due regard to the coming of spring, we reap an autumn harvest; and so in all things we prosper by harmonizing our actions with those of nature. But it is vitally necessary to distinguish between a change that is true progress; and the destructive changes, or reversions toward barbarism, which are the opposite of progress.

The more we contemplate this question of right and wrong behavior, the more we realize that it is not simply a question of ethics, but of wisdom in judging the probable future effects of present actions. It has been well said that the essence of wisdom consists in being interested in subjects and devoted to ends in degrees proportioned to their intrinsic and relative importance. In this sense, a wise man will never allow himself to seek a personal good save in conformity with the conditions of universal good.

The Nature of Happiness

Let us now compare the simple principle that right consists in furthering the progress of organic evolution, with the abstract idea of moralists that right consists in the promotion of human happiness. To an outside observer, who did not himself feel the emotions of pleasure or pain, the theory that happiness could itself be an object would be unimaginable, though he could readily appreciate the tangible object of life expansion in which evolution consists. However, is there not a close correlation between the promotion of happiness and that of evolution?

Happiness broadly consists in the free exercise of one's abilities. Any restrictions cause unhappiness, whether imposed by man or nature. Any unused ability leaves undeveloped a source of greater happiness. I do not doubt that even the termite, condemned to incessant toil in subterranean darkness, derives a strange joy from its monotonous activities, that makes its life worth while. The state of greatest happiness is that in which the world's abilities are being most freely and fully exercised, in work and in play.

A child, forgetful of the past and unmindful of the future, finds perfect happiness in romping with his playmates. The happiness of an adult, however, requires satisfaction of his abilities to enjoy past remembrances and future prospects, as well as fulfilment of his immediate desires. The more complex a personality, and the more varied his abilities, the more difficult it is to secure

a balance of satisfactions, but the more intense and elevated the happiness it is possible to attain. Through the ages man's happiness has progressed from the exultation of the savage after a successful hunt to the enjoyment of the builder in the completion of a great structure—from a momentary thrill to a sustained satisfaction—but always the greatest joys have come in the completion of constructive efforts.

It is reported that Genghis Khan once asked a young officer of his guard what his ideal of happiness was. After some thought, the young man replied, "To ride on a swift horse over the open steppes with a falcon on the wrist." "Nay," the Khan replied, "it is to see your enemies fall before you and hear the lamentations of their women."

There are so many kinds of pleasure, therefore, some transient and some lasting, that to seek happiness directly gives no definite objective. To further progress by exerting constructive efforts brings happiness as a by-product, but the pursuit of pleasure is by no means sure to promote human progress. The defect of the hedonistic principle is that no guide in the selection of pleasures to be sought after is provided. This is remedied by the conscious endeavor to promote evolution itself. Our system of natural ethics includes the best features of the Calvinist and the Hedonist philosophies.

To promote the slow process of evolution, it is clearly necessary to look to the future, to sum up all the effects, far and near, of our actions, and to weigh carefully the net progress resulting. The principle here enunciated is that those actions contributing most to evolutionary progress are right, but it is also indicated that the same actions will produce the maximum total of happiness. Thus, transient pleasures may as often be wrong as right, but enduring pleasures founded on achievement are surely right. By keeping in mind the promotion of evolution as the objective, we are enabled to lay down a true tangent to the curve of progress, as viewed from our own situation. By seeking immediate happiness alone, we may be as far from the true direction as if we took the direction of a single mile of the Mississippi for the true course to its mouth.

The increase of our abilities as evolution proceeds brings with it an increase in our capacity for happiness, which indeed may be measured by the extent and variety of our abilities. Our capacity for suffering is likewise increased, and in periods of retrogression the net effect may be an excess of suffering. But this can only result from a great restriction in the exercise of human abilities; so that it seems a truism to say that the rate of progress of evolution is in the long run proportionate to the existing degree of happiness.

Acceptance of these principles brings at once a train of interesting corollaries. As the abilities and needs of an elephant, a Kaffir and an Eskimo differ, so do the acts which make them happy or promote their progress vary. How widely, then, must their standards of rightness differ, standards which will most conduce to increase in their respective states of ability! What is right for the German is not necessarily right for the Chinese; though with increasing similarity of abilities the standards of rightness are also more alike. From this view-point the absurdity of imposing civilized moral standards on savages is apparent.

Also, we can see that conflicts between nations must arise, even though both act with perfect rectitude according to their own limited standards. The more complex questions of the justice of particular conflicts, and of the right standards for mixed populations, require further recourse to observation of nature's methods. The central fact of evolution is the increase of total fitness for living, or, as applied to man, of his control over nature. When a higher race supplants

a lower one, the world's fitness total is increased, but when the lower race is destroyed or repressed, the total fitness is decreased by that amount. There can be no exact statement of the ethical ideal, but there is clearly a best compromise, in which the lower race allows the higher one to occupy its territory, the higher race aids the development of the lower one, and finally the abilities of the two are perpetuated in association. Thus, a war of aggression is wrong, but so is it wrong to bar unused territory from development; or bar progress by other means; so that wars, revolutions and strikes may often be more right than wrong. As long as groups of men of widely different abilities live apart from each other, so long will conflicts of actions that are right for each of them occur and wars continue.

The conclusions derived from our study of human progress, thus far, are that rightness consists in promoting the free exercise of ability, and this in turn provides true happiness. And the state of evolution is measured by the amount of the world's abilities, the rate of progress of evolution is indicated by the degree of happiness and the rate of acceleration of progress by the degree of rightness existing in the world.

The Nature of Progress

To decide any actual question of right and wrong, it is necessary to define more clearly what progress in evolution is. Progress is like the growth of a giant oak—there are many branches, and no one can say which twig will be the foundation of the greatest future growth. In a broad way, the tree's branches all point upwards, and each year the number and complexity of the offshoots increase—similarly in human evolution progress is always toward greater control over nature and greater variety of man's abilities. This view, therefore, may tell us broad distinctions between right and wrong, but tells also that many different actions are right under different circumstances, and gives us only a hint in the many cases where right and wrong are nearly balanced.

Just as we predict the future growth of a branch of the oak will be along the direction of its present extremity, so the historian studies the records of the past to deduce from them the trend of progress, and so to focus human efforts on practical objectives. Of all the lines of progress made by man, there is none more evident and continuous than the increase of his control over nature, so that we may accept it as a fact that progress in this direction will continue in the future and at an increasing rate. The key to human progress, therefore, and to determination of ethical actions is an understanding of the way in which engineering progress occurs.

Man's control over nature has come from three distinct sources: first, his individual abilities developed through ages of competition; second, his ability to cooperate with his fellows, and thus to specialize; and, third, his ability to provide stable human relations during which constructive projects can be planned and carried out.

Man's individual ability developed at first through the struggle for survival, and later through more and more intensive education. As any further increase in ability is certainly in the direction of progress, we conclude that promotion of education and health are foremost in ethical precepts. Whatever improves either of these two factors is morally right and deserving of all support.

The ability to cooperate, which has so vastly increased man's powers above the aggregate of individuals, has come as a by-product of the development of specialized abilities. Having developed any special skill, a man derives more pleasure from its exercise, both directly and in return for his labor, than in other ways, and so he concentrates on it exclusively so long as he can get others to supply

his additional needs. To effect this exchange of services, cooperation is required, and by continual exercise of this cooperation the skill in working together improves further.

As in the case of any sport, skill is acquired by practice, so that the more one specializes in any useful task the more production can be increased, and so the process is cumulative. Each increase in ability encourages further specialization, and requires greater cooperation, so increasing the variety of skills, the adaptation to surroundings and general fitness for life. In this way, evolution progresses ever more rapidly in each isolated community, until some limit of resources is reached or some conflict with other groups interrupts the course of events.

Cooperation and Sympathy

In just what does the ability to cooperate consist? Evidently it consists not merely in the ability to transfer knowledge from one mind to another, but also in sympathy, the ability to understand and appreciate the feelings of another. Sympathy is the prime requisite for cooperation. The faculty has developed along with the specialization of functions, and its great survival value, due to the increase of power it permitted, has promoted its high development in the dominant races. Admitting only the initial existence of the will to live, and the observed fact that exercise of an ability strengthens it, the development of sympathy follows in the course of evolution as naturally as that of any other of man's varied abilities. The immediate motive to act in accordance with the dictates of sympathy comes from the transference of the feelings of another to one's self and the consequent experience of pain or pleasure. A deaf man may enjoy a concert simply through the pleasure communicated by the expressions of others, and such communications of feeling are felt particularly strongly when watching children, because of their simple emotions and frankness. How much greater enjoyment is possible to one who can feel at once the pleasures of a hundred others, than to another whose lack of sympathy limits his feelings to the pleasures of his own five senses! Sympathetic actions may be called selfish in the second degree, since they are performed to relieve one's own feelings, even though these feelings are simply mental reflections of another's realities.

If this view is correct, the development of sympathy must be one of the most characteristic phases of man's later progress, and its further increase is of the highest practical importance. It is, therefore, worth while to see what we can find out about it from a brief review of history.

It is certain that ages ago men were far less capable of sympathy than they are to-day. Herbert Spencer has suggested that so long as men are hunters and warriors exposed to continual contact with suffering and death, the ability to sympathize with others must remain undeveloped, since exercise of it leads so often to pain. It seems more likely, however, that all developing races have had enough surplus of happiness to make the exercise of a selective sympathy predominantly pleasurable, at least between members of the same race, but that the real development of this ability began when it acquired an important survival value through permitting specialization.

The earliest development of sympathy was between mothers and children, and later it appeared between members of a tribe. The nurses in an ant colony will fondle the baby ants in their arms most affectionately, but will kill strange ants on sight. Savages enact barbaric rites without feeling the least sympathy for the victims, although they regard their relatives with affection. In deserts and very cold countries, where man can not progress beyond the stage of the hunter,

sympathy with aliens has practically no survival value and may even be detrimental, so here it may be ethically wrong.

An English magistrate in India some years ago in visiting a village in his district met with a curious example of this lack of sympathy with strangers. The headman in showing him around passed a steep-sided clay pit full of water, and on doing so began to laugh immoderately. After some difficulty in overcoming his mirth, he explained it by saying that a few weeks ago a stranger, passing by, had fallen into the pit, and had attracted attention by his cries as he tried to get out. The villagers had gathered about and had been so amused by his strange cries and struggles that they had rolled on the ground with laughter until finally he disappeared beneath the surface. It had never occurred to them to help him, much less to recover his body afterwards. This insensitivity to the suffering of others seems to have been quite universal not many centuries ago, so that the development of our present sympathies is one of the happiest signs of continuing evolution.

I believe it was St. Thomas Aquinas in the thirteenth century who held out to his disciples the hope of an especial reward of virtue, consisting in having a front row seat among the angels in heaven, where the tortures of the damned could be enjoyed most heartily. If a saint had such feelings, the populace could scarcely have been sympathetic, and I venture to say their powers of cooperation must have been very slight.

Even after a marked degree of sympathy with other human beings has developed, a complete insensitivity to the feelings of animals has existed. Only recently have the pleasures of hunting come to seem somewhat barbaric, and as late as 1840 a conjurer in Paris achieved great popularity by publicly executing numbers of pigeons and canaries and performing sleight of hand tricks with their remains. Such insensitivity to animal suffering must be a mark of a low order of human sympathy as well. Abraham Lincoln proved his great capacity for human sympathy when, dressed in his Sunday best, he encountered a pig stuck in the mud. After some consideration, he passed by on the other side of the road, but when he had walked a half mile his feelings for the pig had risen to such a pitch that he returned and helped the pig to dry land, at much cost to his clothes.

Elihu Root, when an old man, once said: "Even in my time compassion not only for human beings but also for animals has grown. I distinctly remember that, when Henry Bergh founded the Society for the Prevention of Cruelty to Animals, he was looked upon as more or less of a crank. To-day a man who is cruel to animals is regarded as a brute. It is this growth of compassion that I would say was the greatest change that has occurred in my lifetime."

While the personal capacity for appreciation of the feelings of others has reached a high level in the advanced races, it is still totally lacking in many parts of the world. Also, the capacity for sympathy between cities, states and nations is progressively less as the size of the group increases. Trade barriers, racial discrimination, oppression of minorities and war all demonstrate the inhumanity of large groups. Nevertheless, much progress has been made, and the potentialities of radio and television, airplane travel and improved news service in developing international understanding and sympathy are immense. At present, the perversion of radio and news services in dictator countries to exclusive development of national self-pity, and of hatred for foreign devils, is promoting nationalism at the expense of world progress. But history suggests this is only a passing phase, and that ultimately the ever better media of communication will bring sympathy and co-

operation between nations as well as individuals.

Progress of this sort is especially evident in business methods. A few years ago, the president of the National Electrical Manufacturers' Association offered a series of pledges to guide business competitors, in recognition of their responsibilities to the industry, the last pledge being "To refrain from introducing any practices to gain individual competitive advantage, which if followed by my competitors generally would be uneconomic or commercially unsound." Contrasting this typical modern business precept with the "dog eat dog" practices of early days, indicates how much has been gained.

Broadly speaking, as evolution progresses, interrelationships multiply, and the economic gain from cooperation increases at a continually greater rate. The ethical precept that any act which promotes the growth of sympathy is right, therefore, coincides with the trend of progress in civilization.

Honesty

In nature, growth is slow, destruction is rapid. An earthquake, a fire or violence may destroy in a moment the work of many years. So also in human activities, any constructive enterprise requires much time for planning, organizing and executing. Just as a plant can not grow if its roots are continually disturbed, so human affairs can not go forward unless there is a reasonable degree of stability in society.

The essential criterion of stability is such continuity of physical conditions, laws and contracts that predictions made well in advance will be reasonably fulfilled. When men can not foresee a favorable outcome of their ventures, enterprise fails and business stagnates. Nothing is more destructive of human progress than sudden or arbitrary changes in conditions, whether by criminal act, war, or caprice of a dictatorial government.

Honesty is the human trait which provides this stability. The Anglo-Saxon business tradition that a man's word should be as good as his bond is the cornerstone of progress in civilization, since it has enabled vast business enterprises and creative undertakings to be carried through with assurance. The Machiavellian precepts of double dealing, on the other hand, have given rise to the saying, "Put not your trust in princes," which applies as well to modern as to ancient dictators.

Without honesty, all forms of saving and consequent earned leisure are greatly retarded. Wherever men's promises can be relied upon, and property is safe from thieves, it is possible to store up reserves, undertake new ventures and organize far distant forces to cooperate in great undertakings. Where thieves and liars rule, men's energy is diverted from constructive to defensive actions, no man saves ahead for fear of loss, and society disintegrates into warring factions.

The true criterion of honesty is not merely adherence to a code of ethics, but acting in such manner as to promote long-term constructive activities. When Schopenhauer justified lying in self-defense, therefore, and Talleyrand went so far as to say that words were given to man to conceal his feelings, they were not completely unethical. Honesty in the sense of our natural system of ethics requires adherence to contracts openly arrived at, at whatever personal disadvantage, since such conduct enables the world's business to go on. It does not require, however, that we cooperate in the same manner with an enemy or thief who has invoked the law of the jungle by an act of violence that has disrupted our affairs. Honesty is a by-product of cooperation in much the same way that cooperation is a by-product of specialization.

Conclusions

It is rather striking how the great importance of sympathy indicated by these principles, deduced from the progress of evolution without regard to metaphysical or religious codes, agrees with the emphasis laid on mercy by the Christian religion, on compassion by Schopenhauer and on the same general motive by many other philosophies.

It has not been possible in these few pages to adequately show the relations between human progress and the activating motives which have gradually brought it about, but at least there has been indicated the possibility of a dynamic science of ethics which defines right human actions as those conducive to progress at the time. In primeval times, the exercise of sympathy and honesty can have been of very little importance in the promotion of evolution, and so they were not as ethically important as the exercise of strength and activity. Now, however, the peaceful and helpful intercourse between nations, which is so essential for world progress, requires greater sympathy and honesty on the part of the dominant groups than ever before, and the same qualities are daily more necessary in the conduct of modern business.

The whole point of view that correlates ethics with progress leads away from the old dicta that whatever is is right, and whatever was was wrong, to the new one that whatever is was right. Whatever has come to pass through the processes of evolution has by the very fact of its survival been the product of acts that were right at one time, but the mere fact of their association with conditions no longer tolerable is presumptive evidence that they are right no longer. What is right is change along the lines of progress mapped out by past events.

Applying these precepts to modern society and the present world conflict leads me to hearty concurrence with the ideas of Walter Lippmann, as expressed in his treatise on "The Good Society," and with those of Wendell Willkie, as expressed in many public utterances. The necessities of free enterprise for progress, and of sympathy for cooperation, are so great that I consider the collectivist philosophy of regimentation from above essentially destructive. It is true that codes of fair practice and regulations of many sorts are needed to prevent liberty from degenerating into license, but these will develop far better through growth than by compulsion. Very many useful projects and educational advances are prohibited by any dictator type of government for every one that is aided, leading to ruthless oppression of the most enterprising people, with the inevitable end result of poverty, war and revolution. Dictatorships are as archaic in this modern world as the empire of Darius. They represent, however, the ambitions of millions of men who think by this means to improve their condition, and a crucial struggle for survival is now under way between the two systems. All of us are taking part in this struggle, in one way or another, giving ample cause for renewed thought on what is right and what is wrong.

It is no longer possible to secure general adherence to arbitrary principles of right and wrong laid down by authorities. To build up anew an ethical sense that can permeate a whole nation, it will be necessary to develop a scientific and dynamic ethical theory that justifies the actions of our forefathers as right in their time, but shows us that continuing evolution has made it right for us to be far more sympathetic and more honest than our ancestors could ever have been. One of the greatest opportunities in modern education is to build up such a theory and teach by historic examples the real value of cooperation and the harm done by dishonest actions.

THE PHILOSOPHICAL BASIS OF PEDIATRICS

By Dr. FRANCIS B. SUMNER

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SOME of my readers may have been told that pediatrics is a branch of medical science, and may be wondering at the audacity of a mere doctor of philosophy in venturing to discuss a topic which so plainly falls within the province of the *real* doctor, meaning, of course, the doctor of medicine. However, let me at this point give the reader a word of caution: don't believe everything that is told you! The pediatrics which I wish to discuss very briefly here is the science of the P.D. This is not, however, the P.D. that some of you may be thinking about—the one whose equation you have seen in learned treatises on electricity. No! the P.D. of the present discussion belongs neither to medicine nor physics, but to demonology.

Now before the reader dismisses demonology as mere superstition or plain nonsense, let me ask him to do a bit of introspection. Are we not all demonologists at heart? Why do we—every one of us—indulge in profanity when anything goes wrong? Is this not a vocal protest against some malevolent influence that we feel, for the moment, is balking us and thwarting our efforts? Let us not try to tell ourselves that we never really believe such a thing. I insist that, for the moment, we do really believe it—the moment when those sulphurous words are rolling off our tongues. One's spontaneous utterances reveal one's beliefs in a very true sense, even though some of these beliefs may be quite ephemeral. It is the burden of my present discourse that these momentary beliefs are actually fleeting glimpses of reality.

In theory, we all have complete faith in rigid causation. When the causes are the same, we say, the effects must be the same. But this is contradicted by everyday experience. Most of all, is it contradicted by the experiences of us scientists who are loudest in proclaiming our faith in universal law? In repeating a laboratory experiment, for example, precisely the same procedure is frequently followed by very different results. On such occasions, of course, we piously assume the existence of some undetected difference in the conditions with which we started. But is not this mere dogma or downright superstition? The science of pediatrics is founded on the frank recognition that such is the case.

During the nineteenth century, a thriving branch of mathematics was based upon the assumption that the geometry of Euclid—or part of it—was phony, that parallel lines would be found to meet if only one had the patience to follow them on forever. In the present century, too, we are told that if one traveled at the speed of light, he could make a trip entirely around the universe, retaining his own youth meanwhile, but finding, upon return to his starting-point, that everyone else had grown old during his absence. And again, a British astronomer, so celebrated that he appends nearly the whole alphabet to his name, has gravely assured us that "the number of particles—electrons and protons—in the universe is of the order of 10^{79}." Alas, those figures are already out of date, since at least three new species of sub-atomic particles have been described since that census was taken!

Thus, in founding our science of pediatrics, it is plain that we need not be hampered by any considerations of common-sense. Why may we not assume

that causality needs, in its operations, a silent partner, the P.D.? Before going further, however, I must digress to explain what those mystic letters stand for.

The circumstances which prompted their first utterance will furnish a typical illustration of pediatric phenomena in general. It happened on the Florida coast, in the days when I was trapping *Peromyscus*. Three years earlier, in the same territory, with the same traps and bait, I had no trouble in catching any number of these fascinating little rodents. Now they simply wouldn't enter the traps. Not that they were scarce where we were trying to catch them. Their tracks were abundant everywhere, right up to the doorways of our traps themselves. Days passed by without success. Our time was limited, and much money and effort had been staked on this enterprise. My scientific reputation was on the point of reaching a new low. The situation began to look desperate. It was at the close of another of these days of failure, that I remarked feelingly to my assistant—and I meant it!—that whether or not I believed in a personal deity, I certainly believed in a Personal Devil. And thus was born the P.D.—Devil or Demon, according to your taste.

Our P.D. is not to be confused with the celebrated "Demon" to whom the physicist Clerk Maxwell assigned the task of sitting beside a trap-door between two chambers filled with gas, and sorting out scurrying molecules of different velocities, admitting them to one compartment or the other according to their speed. This demon's only accomplishment was to thumb his nose at the second law of thermodynamics. Our P.D. is a far more versatile being than that, extending his activities throughout the entire universe, wherever there is mischief to be done. The name of the new science which deals with his activities is, as my friend and colleague Dr. D. L. Fox points out, a particularly fitting one, for it plainly means P-D-at-tricks.

To return to our rodents, the spell was eventually broken—how this happened, we don't know—and we were able to ship home a sufficient number of the animals. But that is no part of the present story. For more than a week, the P.D. had complete command of the situation.

There are those who seem to be far less interfered with by the P.D.'s machinations than I am. Perhaps they sprinkle holy water around more freely than I do. In the laboratory, such persons always seem to get out of their experiments exactly what they are looking for. Everything is consistent and in accordance with theory. Inconsistencies and exceptions simply do not exist in their universe of discourse. At times, I cannot help envying such persons. But I am always suspicious of them. This world simply isn't constructed that way.

For honest people like you and me, a typical series of experiments runs about as follows. Our first attempt gives us precisely what we want. The second one confirms our first finding. We begin to get excited and glimpse visions of mighty achievement. However, for a time, we prudently keep our silence. But after another confirmation, we call in our friends; possibly we even commence our manuscript. It is at this point that the P.D. takes the wheel. As a result of some unknown cause—for we still think in terms of causes—things begin to go wrong. Exceptions pile up until they outnumber the rule. Our discovery turns out to be just another mirage. We may spend the next few days or weeks trying to find out which one of our experimental conditions has been unintentionally altered. But we rarely succeed. The real variable is something immaterial. Its name? I have already told you.

Any resemblance between this pedi-

atric doctrine of mine and the so-called "uncertainty principle" of Heisenberg *et al.* is, as the radio men say, "purely coincidental." The P.D. never allows himself to become entangled in a maze of mathematics such as enmeshes the uncertainty principle. He stands forth stark naked for what he is, to be judged on his merits, if any, by the most hopelessly non-mathematical person amongst us.

Every science has its "laws," or principal generalizations, to which its data lead. Thus far, only two laws of pediatrics have been firmly established. Others may be discovered in time. Here are the First and Second Laws of Pediatrics:

Law 1. Identical causes lead to identical results only in so far as an immaterial principle, the P.D., permits them to do so.

Law 2. This principle is malevolent, in the sense that these interferences with the principle of causality tend toward the maximum thwarting of human desires.

Trivial illustrations of these principles meet us at every turn. For example, the oft-confirmed fact that if we try to open an unfamiliar lock with the keys of a bunch, the correct key is nearly or quite the last one to be selected. Stated in more general terms, if we have *n* objects of a particular sort in a group, and if we wish to find some one of these objects, say *b*, by random selection, the probability is high that we shall not find this object until we approach the *n*th member of the series.

I must admit that I have thus far failed to obtain decisive statistical proof of this proposition, however well supported it is by all human experience. That is not strange, however. One must not try to employ scientific standards in a pediatric world. Or to speak more technically, a scientific yard-stick can not be applied to a pediatric frame of reference. (Here again, let me insist that any resemblance between this line of reasoning and that employed by expositors of the relativity theory is purely coincidental).

All this means the downfall of classical science—the science of unswerving causality. Soulless materialism no longer shall rule our minds, and freedom asserts itself once more in the universe. Of the various freedoms concerning which we have heard so much in recent months, there are three which chiefly interest me. These are freedom to jest, freedom to ridicule, and freedom to try the patience of one's readers. But the last of these is the most precious of all. Farewell!

BOOKS ON SCIENCE FOR LAYMEN

ONE HUNDRED YEARS OF MEDICINE[1]

IN the words of the author, this book "traces the major ideas upon which present-day medicine is founded." Great discoveries are rooted in the ideas current at the time. Although, as the title indicates, the author deals chiefly with events in the last hundred years, he takes the reader back into earlier centuries for the background of his account. The book traces the successively developed ideas of the cause of disease: "the wrath of God;" living contagious agents; food deficiencies; endocrine disorders, and finally the idea of psychic causes of disease, and the yet to be studied part played by the "soil" in which the seeds of disease fall. It traces the efforts at conquest associated with these various concepts. The author describes not only the progress of medicine, but also the concurrent opposition and obstruction that have beset all progress, and accounts for some of this, at any rate, in the momentum of ideas that leads even men of intelligence to brush aside new notions with impatience. The momentum of the concept of germ causation of disease delayed for long the recognition of food deficiencies as causes. "The world of science was not as yet responsive to ideas on non-bacterial, non-toxic disease causation."

The book is not solely a history of ideas. It contains many names and dates, and certain great personalities are treated at some length, notably Pasteur, Ehrlich, Koch and Freud. The author points out, however, that the "heroes in medicine" owe much to the stream of thought in which they were born, arising as they do at "nodal points in time." An idea may be expressed by some earlier seer even centuries before that "nodal point in time," but then only, reexpressed or even rediscovered, does it win the recognition that establishes it securely in its science. This thought is illustrated by a number of examples, from Hippocrates down to modern times.

The author is obviously impressed with the dramatic importance of some of the events he chronicles, and has the necessary command of words to convey this to the reader. Speaking of the Black Death: "Not soon forgotten was this visitation, nor those which down to almost our very own age periodically afflicted the world. Grey-haired men told of the 'pestilence' to their sons, and they in turn to their sons; and dread was upon all men. A pale horse, the fourth of the Apocalypse, rode upon the winds, and he that sat upon it was death."

The author brings out some interesting facts in the history of sepsis in surgery. From about the second century, A.D., surgery began to fall into disrepute, and finally was abandoned to the barbers and even to traveling charlatans. Only in the eighteenth century was it taken up again by reputable medical men. The author attributes its decline in the Dark Ages to the rise of sepsis in those centuries. The Hebrews, Greeks and Romans were clean peoples, but the Europeans in this era had become almost deliberately dirty. This is attributed to the development, under the influence of Christianity, of the idea of "mortifying the flesh"—by dirt and vermin.

Strangely, it appears that in the middle of the nineteenth century, after John Hunter had restored surgery to respectability, deaths from sepsis rose enormously. Mortality from amputations in Scottish hospitals, previously 8 per cent. or less, rose to 33 per cent.; and Lister's amputations had a mortality of nearly 50 per cent. before he began the development of his antiseptic methods.

[1] *Progress in Medicine.* Iago Galdston. ix + 347 pp. 1940. $3.00. Alfred A. Knopf.

It is interesting to contemplate that the field of nutrition was considered to be "worked out" at the beginning of the present century, when the work that must be regarded as starting the avalanche of present-day vitamin research had just been finished. Eijkman in 1897 had proved that a diet of polished rice resulted in the development of beri-beri. The scientific world slowly woke to its significance, and the science of nutrition had a rebirth. It "has helped free medicine of its germ-obsession, by demonstrating that there are diseases due to causes other than the contagium vivum. It has drawn attention to the soil as against the seed, compelling a revision of thought on the disease-producing powers of germs and their toxins."

The author gives an interesting account of the history of endocrinology. The idea that some part of an animal's body, when fed to a patient, affected favorably the same part of his own body, goes back to antiquity. As early as 1660 Thomas Willis proposed that the genitals contribute something—"a certain ferment"—to the blood, that gives the blood a "lively virtue." In 1858, Brown-Sequard experimented with the adrenals, and years later administered testicular extract to himself. In endocrinology, however, as with the vitamins, the impetus for wide-spread research came from efforts at conquest of a disease. Cretinism was the disease; its association with the thyroid was first discerned in 1603 by Paracelsus. The author portrays the unfolding of knowledge of the gland and its functions. "The greatness of the [early discoveries regarding the thyroid and cretinism] was not so much in the explanation of the origin of a specific disease or in the development of a particular remedy. More significant was the clear demonstration of the existence of glands of internal secretion, of their products, the hormones, of new and distinct categories of diseases, of new disease mechanisms. A revolution had been effected in medical thought—not less significant than that experienced in the demonstration of the germ causation of certain diseases."

In a history of ideas the reader expects to find a sympathetic treatment of the idea of psychic causation of disease. He will not be disappointed. The author brings to life the pioneers in the use of hypnotism, notably Mesmer and Elliotson, and traces the development of the ideas of the Nancy School and the Paris School. He then gives a history of the concepts of psychoanalysis and the unconscious, and their discovery and development by Freud; and a brief account of the reform in the care of the insane in this country and abroad.

The last two chapters are headed "A Century of Clinical Progress" and "Whither Medicine." The author comments upon the complexity of present-day diagnostic studies, the laboratory study of the disease versus the clinical observation of the patient, the multiplicity of therapeutic agents, chemotherapy, and upon communal and personal preventive medicine. He considers the benefits to be derived hereafter from studies in nutrition, endocrinology and psychiatry as likely to surpass those already gained through the establishment of the germ theory of disease, and believes these studies will profoundly change the practice of medicine. He finally predicts that medicine in the future will recognize as its objective not merely the prevention or cure of disease but the realization of each man's greatest potentialities for physical and functional competence, achievement and well-being. The book is good reading for any person interested in medical history, whether physician or patient.

Errett C. Albritton

SCIENCE OF PHOTOGRAPHY[1]

This readable little book by the author of "Soap Films" will be especially use-

[1] *The Scientific Photographer.* A. S. C. Lawrence. Illustrated. x + 180 pp. $3.75. July, 1941. The Macmillan Company.

ful to many workers in fields not directly dependent upon photography, who have occasional need for photographic knowledge beyond that of the casual layman. Some of the best sections, for instance, are on the practical and esthetic aspects of the problem of making a record photograph.

The chapter headings are: The Bases of Photography, The Lens and the Image, The Mechanism of the Camera, Color Photography, Making a Picture, Developing and Printing and Some Scientific Applications. Covering such a wide field at a level well above the most elementary one, in an octavo volume of only 180 pages of large type, is a feat for which the author deserves commendation, especially in consideration of his treatment of many photographically important but seldom mentioned topics such as Rayleigh scattering, diffraction at the image of a point and the illumination problem in photomicrography. The author makes a strong plea for the increased use of motion pictures in education, particularly at the university levels.

Occasionally the discussion suffers from over-brevity, as, for example, in the discussion of the Gurney-Mott theory of the latent image (three sentences!) where the terms "occupied level" and "conduction band" are used entirely without explanation. There are a few erroneous statements, such as the attribution of distortion to curvature of field, the reference to perspective convergence of the verticals as distortion, the confusion of numerical aperture with pupil diameter, the evaluation of the gain factor in mercury hypersensitization at about 20 and the statement that chromatic aberration is proportional to the size of the stop. Although the draftsmanship of the diagrams is in some cases poor (and there are obvious errors of optics in Figs. 20, 22, 24, 26 and 83) the quality of the photographic illustrations is excellent.

JULIAN ELLIS MACK

FOUNDATIONS OR STUMBLING STONES FOR A SCIENCE OF PERSONALITY?[1]

THE announcement of this book begins with the statement: "Human nature has long been studied in its many phases, but a systematic framework for the integration of its manifold aspects has been wanting. Dr. Angyal, drawing upon modern thinking in psychiatry, psychology, philosophy and biology, has constructed such a framework. He has given substance to the idea of 'the organism as a whole' by applying new concepts and working out a closely reasoned system of the laws of personality dynamics."

Certainly individuals or persons have been studied from the directions mentioned, and many others including economics, sociology, political science, history and religion. Any serious attempt to synthesize the segmental attempts to understand people deserves attention; because, in analyzing individuals into their component parts or phases, we have practically lost the individual himself. Alexis Carrel could write "Man the Unknown" not because man is unknown but because many sciences have dismembered him almost beyond recognition.

From these fragments Dr. Angyal attempts to create a new science, a science of the individual, of the person, in short, a science of personality. On page 262 he recapitulates briefly as follows:

"The subject of study for the science of personality is the biological total process. This is a unitary organization of part processes which we call biospheric occurrences. Biospheric occurrences are bipolar processes. The two poles are the subject pole and the object pole respectively. Biospheric occurrences, when considered from the subject pole as a point of reference, appear as manifestations of various dynamic tendencies. These can be traced back to more general

[1] *Foundations for a Science of Personality.* Andras Angyal. Illustrated. xii + 406 pp. $2.25. 1941. The Commonwealth Fund.

tendencies, leading finally to the most general trends, that is, the trend toward autonomy and the trend toward homonomy. The ramifications and interconnections of organismic tendencies represent the subject-dependent organization of the biosphere.

"Biospheric occurrences are influenced also by the connections which exist between the objects of the environment. The biological environment is a constellation of positive and negative valences. This can be expressed even better perhaps in simple language by stating that the environment is a constellation of opportunities and contraventions."

This quotation is characteristic of the book. In this reviewer's opinion, the net result is a jumble of words rather than a system of helpful or new concepts. There is more new material here for the student of semantics than for the student of personality. A teacher of epistemology might well use this book for a case study in whether or not its highly verbalistic system does more to obscure or to illuminate its subject.

HENRY C. LINK

A STUDY OF FOUR YUCATAN COMMUNITIES[1]

ANTHROPOLOGISTS of this country have usually drawn a fairly well-marked line between ethnological studies dealing with aboriginal cultures and those studies they choose to call sociological. Where native communities have been strongly affected by acculturation, emphasis has normally been placed on an attempt to sift out that which was aboriginal from the general mixed content, in an attempt to restore as nearly as possible the pure native picture. No anthropologists has trod more successfully than Redfield that middle ground which presents the total result of cultural amalgamation.

The present study, using the methods of procedure followed in the author's previous studies of Tepoztlan and Chan Kom, achieves broader results than these. "The Folk Culture of Yucatan" consists of a comparative study of four Yucatan communities: a village of tribal Indians, a peasant village, a town and the city (Merida). Working from his own extensive field experience and that of his collaborators, Dr. Redfield has drawn some interesting conclusions as to the working of cultural processes as a result of the impact and four-century juxtaposition of Spanish and aboriginal Maya cultures, under the varying conditions imposed by these four types of community life. The principal processes dealt with are those termed cultural disorganization, individualization and secularization as affecting social, political and religious affairs.

The task of the reader, and incidentally of the reviewer, has been simplified by an explanatory preface and a table on contents giving a digest of each chapter. The conclusions drawn are temperate and strictly determined by the field material. One draws the refreshing conclusion that the theories came after the facts instead of before.

This cross section of Spanish-Indian life offers a most satisfactory model for future acculturation studies in Latin America. Being a study of a region which has been for a long time isolated, it reflects a purely bi-cultural society, which makes it more susceptible of analysis than is the case with the usual polycultural group.

All this is apart from the fact that the reader will find here a vivid and readable account of the life and customs of these people who have worked out their own destinies with but little influence or pressure from the outside.

M. W. STIRLING

[1] *The Folk Culture of Yucatan.* Robert Redfield. Illustrated. xxiii+416 pp. $3.50. August, 1941. University of Chicago.

ROBERT WILLIAM HEGNER

THE PROGRESS OF SCIENCE

ROBERT WILLIAM HEGNER, 1880-1942

Zoology in general and protozoology in particular suffered a severe loss with the passing of Robert William Hegner, the energetic and forceful exponent of medical zoology at the Johns Hopkins University for nearly a quarter of a century.

Dr. Hegner was born in Decorah, Iowa, on February 15, 1880. As a youth he was greatly interested in ornithology and became one of the early devotees of bird photography. He graduated from the University of Chicago with the B.S. degree in 1903 and continued there as a graduate student until he transferred to the University of Wisconsin, where he received the Ph.D. degree in 1908. With the completion of his formal studies he served as instructor and as assistant professor of zoology at the University of Michigan until he was called to the newly organized School of Hygiene and Public Health of the Johns Hopkins University in 1908. Here he began his definitive career, becoming associate professor in charge of the department of medical zoology in 1920 and professor of protozoology in 1922, a position he held with distinction until the end of his life, on March 11, 1942, at the age of sixty-two. He continued his lectures and the direction of his department with fortitude and cheerfulness through his final year of increasing suffering and weakness. Mrs. Hegner, née Jane Zabriskie, and one daughter survive him.

Dr. Hegner's career was one of marked versatility as well as activity. His early investigations on insect embryology led to the publication of his well-known treatise on "The Germ Cell Cycle of Animals." Thereafter his research turned to the field of protozoology and resulted in the extensive series of papers that flowed from his laboratory, year after year. Many were on the general biological aspects of the Protozoa, including genetics, but the majority involved studies on parasitic forms of particular interest in problems of medicine and human welfare. During the last few years he concentrated his attention chiefly on bird malaria and had in progress, when his health failed, what might well have proved to be the most significant series of studies of his fruitful career.

Coincident with his intensive research program and the direction of the research of nearly fifty graduate students, Dr. Hegner found time to publish a considerable number of books, including technical treatises, text-books and popular expositions of zoology. Among them, his "College Zoology," now in its fifth edition, has been remarkably successful and has undoubtedly had an important influence on zoological courses in American colleges. His lighter vein is expressed in "The Parade of the Animal Kingdom" and culminates in "Big Fleas Have Little Fleas," where the layman finds revealed "Who's Who Among the Protozoa."

Furthermore, editorial duties were not omitted. For some years Dr. Hegner served as editor of the Century Biological Series, as contributing editor of the *Quarterly Review of Biology* and as a member of the editorial boards of *Biological Abstracts*, the *Journal of Parasitology*, the *American Journal of Hygiene* and the *Journal of Morphology*.

Such extensive tasks would have largely confined a less active man to Baltimore and its environs, but not Dr. Hegner. He traveled extensively. He was a delegate to the Royal Institute of Public Health at Brussels, Belgium, in 1920, and to the International Congress on Health Problems in Tropical America at Jamaica in 1924. Then he served for

several months in 1926 as exchange professor at the London School of Hygiene and Tropical Medicine, and three years afterwards organized a program in protozoology at the School of Hygiene of the University of the Philippines. A few years later he assisted in organizing work in parasitology at the Institute of Public Health in Mexico City. And incidentally, as it were, from time to time he directed expeditions for the study of parasitic protozoa in a number of tropical American countries, including Puerto Rico, Honduras, Panama, Colombia and Guatemala. From these odysseys he brought home a wealth of data, experience and enthusiasm that were reflected in his laboratory.

Dr. Hegner served as president of the American Society of Zoologists and of the American Society of Parasitologists, and vice-president of the Zoological Section of the American Association for the Advancement of Science. He was one of the founders of the American Academy of Tropical Medicine and a member of the scientific board of the Gorgas Memorial Institute. His scientific contributions were also recognized abroad: he was a fellow of the Royal Society of Tropical Medicine and of the Royal Institute of Public Health and an honorary member of the Mexican Society of Natural History.

We know a great deal more about the protozoa that bother or kill us as a result of Hegner's studies. Many of his students are carrying on in the important field to which he devoted his life. And withal, in the words of one of his colleagues, "he was charming in all his personal relations, and his keen sense of humor and wide experience made him the most interesting and stimulating of companions."

LORANDE LOSS WOODRUFF

OPENING OF THE STUART LABORATORY OF APPLIED PHYSICS AT PURDUE UNIVERSITY

PURDUE UNIVERSITY celebrated the opening of its new physics laboratories on June 19 and 20 with a "Conference on Problems of Modern Physics" to which scientists from all over the country were invited. The conference marked the culmination of a period of physics at Purdue University, a period in which graduate work was started and a research program developed that led to the construction of a large and well-equipped physics laboratory facing the Mall in the new part of the university campus.

The Charles Benedict Stuart Laboratory of Applied Physics was made possible through the generosity of the late Mrs. Alice Earl Stuart. It is a memorial to her husband, Charles Benedict Stuart, a prominent Indiana lawyer of fifty years ago who dedicated his creative citizenship to Purdue University both as a member of the board of trustees from 1885 to 1899 and as president of the board of trustees the last eleven years of that period.

The new physics laboratories were occupied by the department of physics in the fall of 1941. They are devoted to the teaching of engineering, general and advanced physics and to research in the fields of theoretical, experimental and applied physics. The main research laboratories in the sub-basement and on the ground floor are partially air-conditioned to insure constant temperature conditions.

The radiation laboratory housing the Purdue cyclotron with its newly developed accessories is devoted to research in nuclear physics and the use of radioactive tracers in biological, agricultural and metallographic problems. A special vibration-free grating room provided for the installation of a 30-foot grating in a Paschen mounting is the center of the

spectroscopic laboratory for work in atomic and molecular spectral analysis.

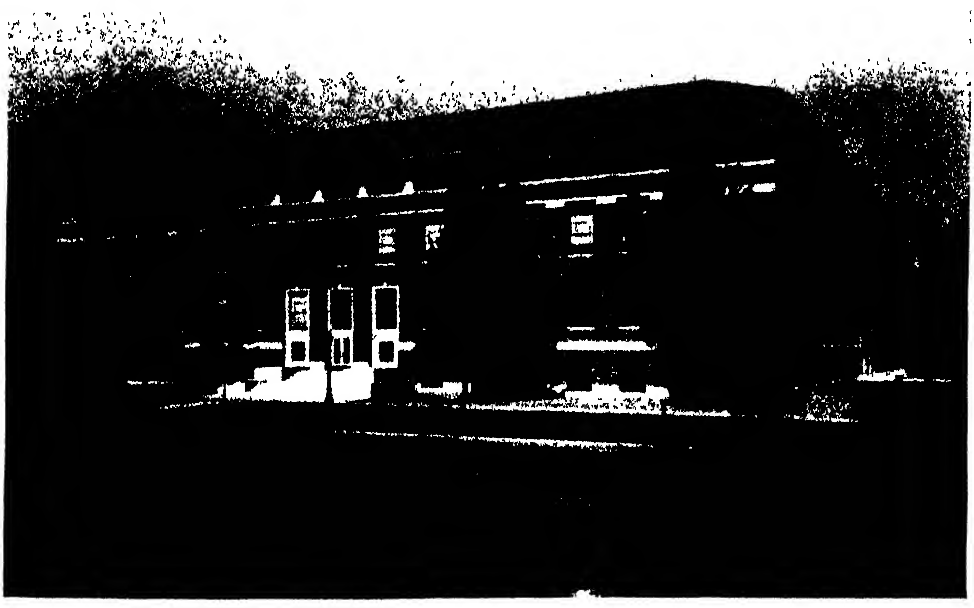
On the ground floor of the laboratory are elaborate acoustical laboratories as well as a wide range of facilities for work in the conduction of gases and in applied nuclear physics; in the same wing are the electron diffraction and x-ray laboratories. These are fully equipped for investigation in the structure of matter and the study of industrial problems.

Laboratories for the use of students in engineering, general home economics and intermediate physics, on the first and second floors, are conveniently grouped about the main apparatus room. Also on the second floor are offices for those working in theoretical physics, a library, a conference room and the departmental offices.

The main lecture room, which was used for the chief sessions of the conference, has a seating capacity of 300 and is air-conditioned. Smaller air-conditioned rooms are available for group discussions. The precision instrument shop, the faculty machine shop and a glass-blowing shop equipped with precision machine tools are conveniently near to the teaching and research laboratories.

Besides the special laboratories are twelve large undergraduate ones, ten recitation rooms and two lecture rooms. The total floor space of the building is 95,000 square feet.

Professor Karl Lark-Horovitz, head of the department of physics at Purdue University, emphasized the importance of all branches of experimental, theoretical and applied physics at the institution on the occasion of the dedication. He was followed by a response by Mr. Allison Stuart, a member of the board of trustees and a nephew of the benefactress. Dr. Lark-Horovitz then introduced Dr. E. U. Condon, associate director of the Research Laboratories of the Westinghouse Electric and Manufacturing Company, who gave an opening ad-



THE CHARLES BENEDICT STUART LABORATORY OF APPLIED PHYSICS
THE NEW PHYSICS BUILDING AT PURDUE UNIVERSITY, WHICH IS DEVOTED ENTIRELY TO EXPERIMENTAL, THEORETICAL AND APPLIED PHYSICS.

SPEAKERS AT THE DEDICATION OF THE STUART LABORATORY
Back row: PROFESSOR KARL LARK-HOROVITZ, HEAD OF THE DEPARTMENT OF PHYSICS AT PURDUE UNIVERSITY; DR. W. W. HANSEN, ASSOCIATE PROFESSOR OF PHYSICS AT STANFORD UNIVERSITY, AND DR. D. W. KERST, ASSISTANT PROFESSOR OF PHYSICS AT THE UNIVERSITY OF ILLINOIS. *Front row:* DR. W. F. PAULI, OF THE INSTITUTE FOR ADVANCED STUDY AND VISITING LECTURER AT PURDUE; DR. J. SCHWINGER OF PURDUE; DR. E. U. CONDON, ASSOCIATE DIRECTOR, RESEARCH LABORATORIES OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, AND DR. JOSEPH A. BECKER, RESEARCH PHYSICIST, BELL TELEPHONE LABORATORIES.

dress on the subject of "Physics in Industry." Dr. Condon traced the development of physics in America from the founding of the American Physical Society, through the discoveries of Rowland, Hall, Michelson and Millikan, through the great change just after the first World War characterized by a great increase in interest in research, to the present-day rapid expansion of industrial research in the direction of applied physics.

The morning sessions of June 20 were devoted to theoretical physics. Dr. J. Schwinger, of Purdue University, spoke on "Theories of Nuclear Forces." He gave a detailed account of the known facts of two-particle nuclear interactions and summarized the attempts that have been made to explain these interactions through the mesotron field. Dr. W. F. Pauli, of the Institute for Advanced Study and visiting lecturer at Purdue University, gave an address on "Problems of Modern Field Theories" in which he discussed Dirac's latest attempt to eliminate the well-known difficulties still to be found in present theories of the radiation field and its interaction with matter.

Dr. D. W. Kerst, of the University of Illinois, spoke in the afternoon session on "The Design and Construction of the Twenty-Million Betatron." In his lecture he explained in considerable detail the nature of the various special devices used in the proper operation of the betatron. Dr. W. W. Hansen, Stanford University and the Sperry Gyroscope Company, discussed the "Physics of Statistical Noise" on the same afternoon.

He described the origin of the Johnson noise and shot effect in electrical circuits and explained the importance of these effects in industrial design.

At the second and final evening meeting of the conference, Dr. E. C. Elliott, president of Purdue University, now active in the coordination of the civilian war training in the colleges of the nation, addressed the group and introduced the speaker. Dr. Elliott urged that every effort be made to fulfill the nation's need for men of physics and expressed confidence that the present laboratory would serve that purpose well. The address of the evening, "The Electron Microscope and its Applications," by Dr. Joseph A. Becker, was a great lesson in the force that the science of physics can muster in the solution of problems that reach far beyond the usual bounds of the science. Among the many applications of the electron microscope discussed by Dr. Becker, perhaps most interesting were the analysis of surfaces, the following of crystalline structural change at transition temperatures, the change in electron emission rates of surfaces and the visual effects caused by single atoms in thermal motion, effects which he showed clearly by demonstrations with a device that magnified one million times in which the motion was clearly visible on a fluorescent screen. JULIAN K. KNIPP

NATURE THROUGH THE ELECTRON MICROSCOPE

ALTHOUGH the electron microscope has been developed some fifty years after the optical perfection of the light microscope, in some ways its present position is comparable to that of the light microscope in the days of Leeuwenhoek. At that time, a tremendous increase in resolving power led to the observation of a whole new realm of natural phenomena which thoroughly confused the science of that day. Interest in the wonders described by Leeuwenhoek spread throughout the centuries and eventually developed into the science of microscopic biology and medicine.

Many of the problems of these sciences involve the analysis, understanding and interpretation of those things which Leeuwenhoek discovered and described. Microscopic analysis developed slowly at first, but as finer instruments were built its progress became more rapid. For the past fifty years, scientists have had the advantage of using the best resolutions that are theoretically possible for the light microscope, and great strides have been made. Even so, there is much which can neither be seen nor understood with the aid of the light microscope. Molecules and many structural details of microscopic subjects are much too small.

The discovery of the wave nature of electrons, thousands of times smaller than the wave-length of light, led to the development of the electron microscope, which gives fifty times the resolving power of the best light microscope. This jump in resolution has opened up a new

FIG. 1. COCKROACH CUTICLE
THIN SECTION, MAGNIFIED 6,000 TIMES.

FIG. 2. FRAGMENT OF A BUTTERFLY SCALE
FROM THE BRILLIANT TROPICAL *Morpho*. MAGNIFIED 13,000 TIMES.

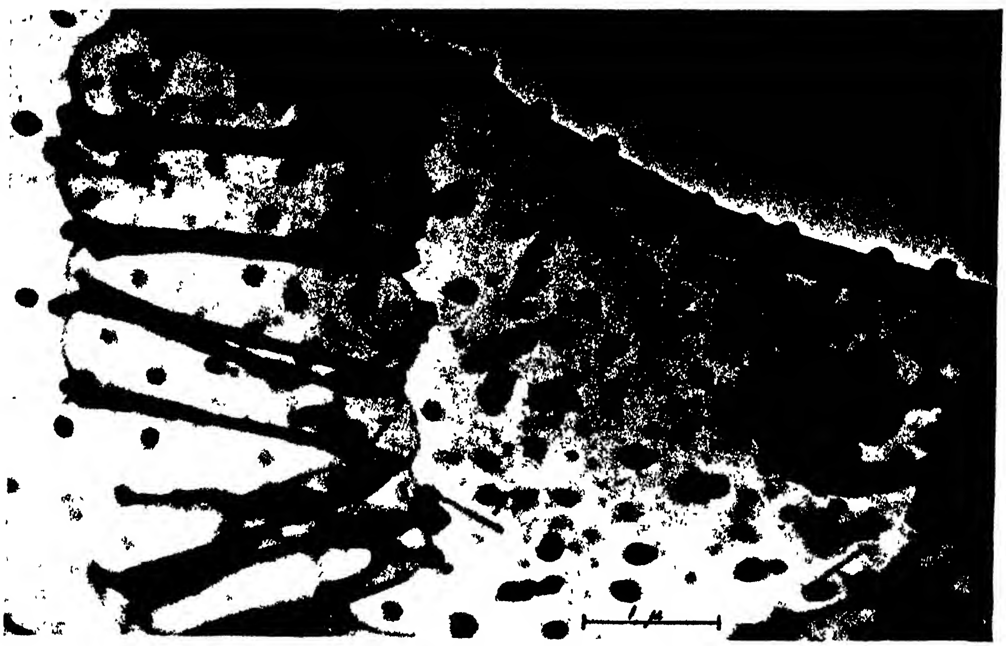


FIG. 3. PIECE OF TRACHEA AND AIR-SAC
OF ROSE CHAFER BEETLE. MAGNIFIED 17,000 TIMES.

world to the sight of man. In exploring the range of application of the instrument many materials, including large molecules, viruses, bacteriophages and bacteria, have been studied and some of their properties determined. In many cases the results confirm the results of studies of the same materials made with the light microscope and other instruments. Frequently, however, as was the case with the first microscope, much of what is seen can only be described—its meaning is not apparent.

The studies of insect material offer examples of both types; on the one hand, definite problems were pursued and solved; on the other, miscellaneous materials were examined to find the range of application of the instrument and to satisfy, perhaps, a natural curiosity as to their nature.

One definite problem which was undertaken was the clarification of the micro-anatomy of insect cuticle or skin, with the purpose of finding the mode of penetration of insecticides dissolved in oils. Fig. 1 shows a cross section of the cuticle of the cockroach *Periplaneta americana.* Sectioned material, thin enough for electron penetration (0.2 μ) proved to be difficult to get, but this one, for example, was obtained by cutting the chitinous sheet free-hand.[1] It is seen that hollow canals (pore canals) only 0.1 micron broad traverse the cuticle in a helical path which is only 0.25 micron broad. From these pictures, it is estimated that there are at least 2,500,000,000 such canals on the skin of a single cockroach! Further work shows that, although insecticidal oils penetrate the skin of the cockroach, they apparently *do not* travel down these canals.

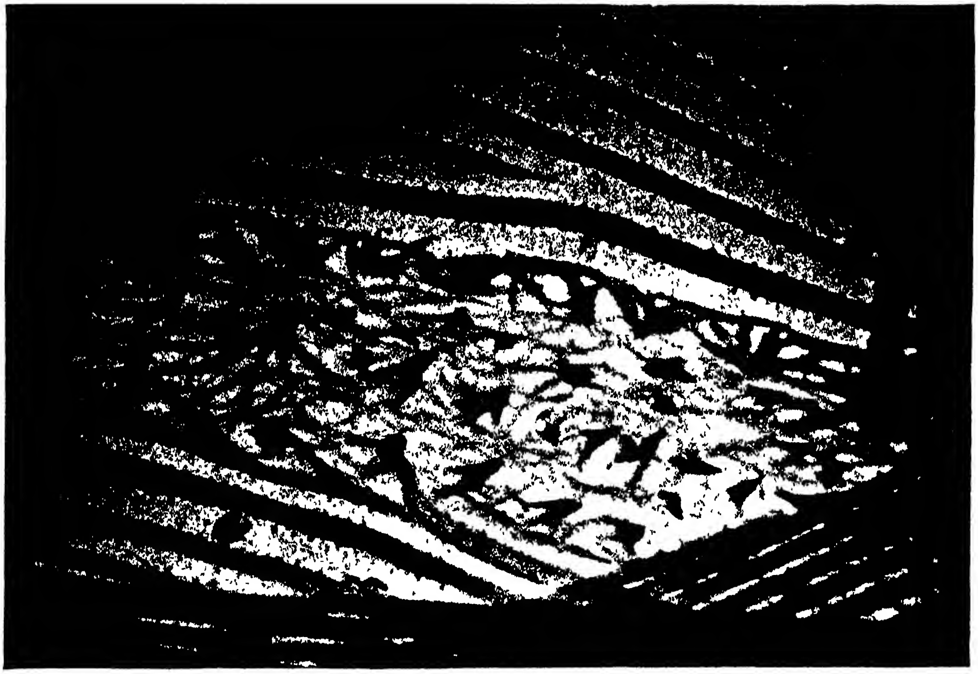


FIG. 4. PIECE OF TRACHEA OF MOSQUITO LARVA. MAG. 7,000 TIMES.

Another subject which has interested physicists and biologists alike for fifty years is the question as to how certain

[1] Richards and Anderson. *Jour. Morph.*, 71: 135-183, 1942.

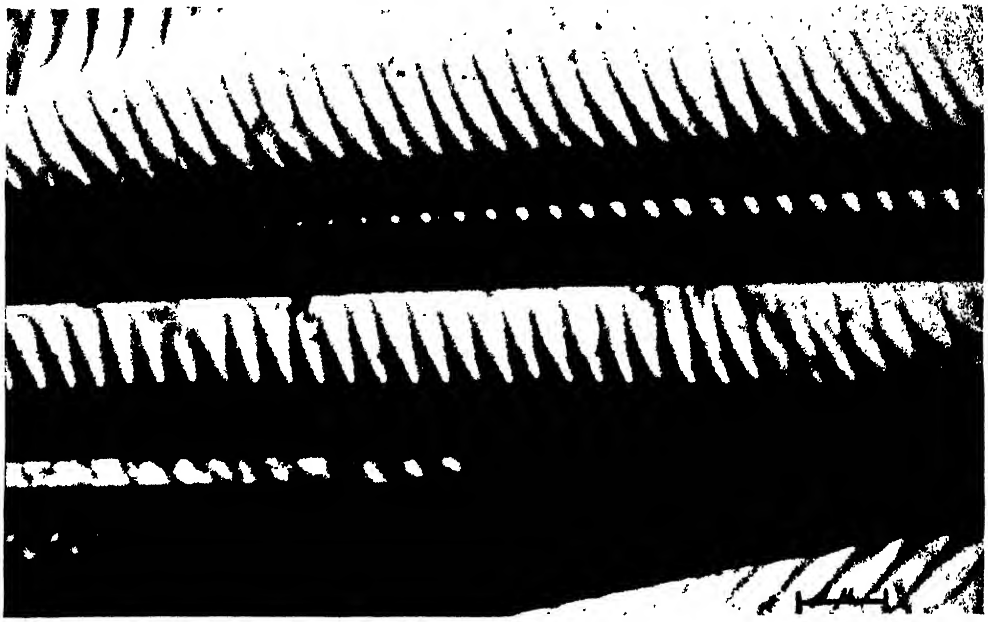


FIG. 5. SETAE FROM MOSQUITO LARVAE. MAGNIFIED 11,000 TIMES

FIG. 6. FRAGMENT FROM EGG SHELL OF MOSQUITO. MAG. 20,000 TIMES.

butterflies such as the brilliant blue *Morphos* achieve their iridescent colors. It has been known for some time that structural elements must be present which act as multiple thin films in reflecting selected wave-lengths. From the effects observed, Mason, Süffert and others have inferred what types of structures must be present, although the elements involved are necessarily below the limits of the light microscope. Fig. 2 shows an electron micrograph of a fragmented iridescent scale of *Morpho cypris* bent in such a way that the iridescent elements are seen in profile on the left while the supporting framework is seen on the right. The lines on the vanes, to use Mason's terminology, are spaced to reinforce blue light in reflection in excellent confirmation of the deductions of the authors mentioned above. The matter does not end here, however, for in other micrographs of these scales details only 0.006 micron broad can be seen which may be related to the arrangement of the molecules of which the scale is composed. A detailed account of this investigation will appear shortly.

Insect tracheae are beautiful objects for electron microscope studies. While the tracheae of almost all insects appear almost identical in the light microscope, marked differences appear when examined with the electron microscope. The trachea of the rose chafer (*Macrodactylus subspinosus*) is covered with little domes which spread to the air sac, seen in the background of Fig. 3, in marked contrast to the spiny trachea of the mosquito larva of which a single layer is shown in Fig. 4. The helical thickenings seen in most tracheae in the light microscope have frequently been found to revert to ring structures in some smaller tracheae, such as that seen on the left side of Fig. 3, and such thickenings extend even to the tiny tracheoles, 0.2 micron in diameter, an observation which vitiates the classical definition of tracheoles.[2]

[2] Richards and Anderson. *Jour. N. Y. Ent. Soc.*, 50: 147–167, 1942.

If one examines insect material chosen more or less at random, he runs across details of structure which are no less striking. For example, Fig. 5 is an electron micrograph of the comb-shaped setae which form the hairs of the anal brush of the mosquito larva (*Culex pipiens*). The uniform teeth of these combs taper from 0.3 microns at the base to 0.04 microns at the tip. In this print, the relationship between thickness of the object and penetration by electrons is shown by the darkness of the solid walls of both the shaft and the barbs in con-

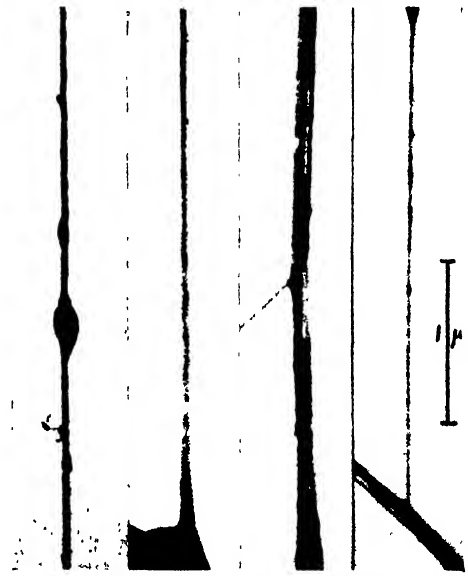


FIG. 7. PIECES OF SPIDER'S WEB MAGNIFIED 21,000 TIMES.

trast to their hollow cores. In the barbs the hollow core extends approximately one third of the way, as is shown by the uniformity of the barb's outer two thirds. The hollowness of the structure is particularly well brought out when the specimen is observed in a stereoscopic picture which is easily done in the electron microscope because of its great depth of focus.

The fragment of a mosquito (*Culex pipiens*) egg shell in Fig. 6 illustrates the delicacy of an insect structure as well as the pictorial quality which can be

brought out in a negative print. Like the rope ladders of an old-time sailing vessel the tiny thickenings, no more than 0.02 micron broad, curve between supporting rods which measure 0.1 micron. The membrane between these thickenings is so extremely thin that it is almost invisible, showing up most clearly at the edges of the torn fragment. Like some other insect membranes, this membrane is probably no more than 0.01 micron thick. It can be seen by reflection of visible light, but the detail can not be resolved.

Symbol of delicacy to the unaided eye, the spider web still appears delicate at electron microscope magnifications. Fig. 6 shows fragments from the web of a species of the spider, *Agelenopsis*.[3] The composite spider threads are relatively large—0.1 micron, but the single fibers shown here attain thinnesses down to 0.03 micron. The relatively large blobs on the threads are droplets of the viscid sticky material that traps the spider's prey.

In other fields, too, examples might be cited in which the principal purpose of an investigation was accomplished, but in which numerous attendant observations in the world of molecular dimensions have been made. In most of these cases the structure and behavior of materials in this infinitesimal world seem strange and mysterious now because of our lack of experience in this world. It is probably safe to say that one day much of what seems strange and arbitrary now will submit to logical analysis.

THOMAS F. ANDERSON[4]
A. GLENN RICHARDS, JR.

THE AAAS-GIBSON ISLAND RESEARCH CONFERENCES

THERE may be nothing new under the sun, but the AAAS-Gibson Island Research Conferences are novel in many respects. They do not consist of formal addresses before general audiences seeking entertainment and possible enlightenment. They are not reported by the daily press. They are not recorded and distributed in proceedings or reports of the meetings. Instead, to paraphrase the closing words of Lincoln's Gettysburg address, they are conferences of experts, by experts and for experts in the broad fields of chemistry and its applications.

Lest it might be supposed that these conferences are only the flower of a bright idea that will wither under the hot sun of experience, it should be stated that for the past five summers (including this one) they have been held in steadily increasing numbers and with increasing success. In the summer of 1938, two conferences were beld, to be followed by three in 1939. In 1940 the number jumped to six, and to eight in 1941. Finally, in this year of total war, with scientists by the thousand serving in the country's armed forces or working on technical problems relating to the war, ten conferences are being held, each covering a period of five complete days, including four evenings.

The success of the conferences has been due to the importance of the subjects discussed, the eminence of the participants and the completeness of the arrangements for holding the sessions and providing accommodations for those attending. Among the subjects of the twenty-nine conferences that have been held, there are found several of special interest because of the war. In 1940, and again this year, the subject of one of the conferences was Frontiers in Petroleum Chemistry. It may be conjectured that in these conferences such matters were discussed as the fundamental principles that underlie the production of high octane gasoline for airplanes and the use of petroleum in producing substitutes for natural rubber. A con-

[3] Identified by Dr. W. J. Gertsch.

[4] RCA fellow of the National Research Council.

ference on the very important and rapidly developing subject of vitamins was held in each of the past four summers. Three conferences have been held on Organic High Molecular Compounds, the chemical basis for the properties of rubber and the synthetic substitutes for rubber.

Drs. Harold C. Urey, Irving Langmuir and James Franck, Nobel prize winners, and other distinguished chemists from both university and industrial laboratories have been participants in the conferences. They have gone to Gibson Island from all parts of the country, from the Pacific Coast, the Middle West and the far South, as well as from the East. Among the advantages of the conferences has been the mingling of men from sheltered academic halls with those who are in close contact with production to meet practical human needs. Together they are pushing forward the frontiers of chemical knowledge, transform life with the products of their discoveries, and educating their successors to go beyond present horizons into regions concerning which at present they vaguely dream.

Probably the AAAS-Gibson Island Conferences owe their great success more to their setting and organization than to any other factor. They are held on Gibson Island, a wooded island of about a thousand acres in Chesapeake Bay, about twenty miles south of Baltimore. The island is connected with the mainland by a causeway, but it is privately controlled and provides its own utilities for the Gibson Island Club and about eighty families who live in their own homes. The island offers excellent opportunities for golf, tennis, both salt- and fresh-water bathing, fishing and sailing. In fact, important yachting regattas are held each summer in the bay just off the island. On the shaded veranda of a commodious building on the highest hill of the island the conferences are held.

As has been stated, each conference continues for five days, beginning on Monday morning and closing on Friday evening. The morning session, beginning at ten o'clock, usually consists of only one formal paper, which is followed by free discussions until time for luncheon, which is taken at the Club. As a participant once said, those joining in these private and unreported discussions "take their hair down and express themselves without reservation." The afternoons are usually left open for recreation and informal discussions by small groups. After an early dinner at the Club, one or two papers are presented at a second session, which is followed by discussions often continuing until a very late hour.

After one of the morning sessions the participants decide whether they will hold a conference the following year. If they decide to do so they elect a chairman and a vice chairman for the next conference and a committee to arrange the program and invite contributions to it by leaders in the field to be discussed. In due time the program is announced and applications are received for the opportunity of attending the conference. When the number of applicants exceeds the sixty who can be accommodated, as usually happens, the program committee decides who among those desiring to participate will make the greatest contribution to the conference.

Naturally these remarkably successful conferences owe their excellence to some individual having vision and very exceptional administrative ability. That individual is Dr. Neil E. Gordon, who was elected secretary of the Section on Chemistry of the American Association for the Advancement of Science in January, 1937. At the meeting in Denver, in June, he asked if he might attempt to organize one or more conferences for the summer of 1938. He organized two, they were a success, and the rest have followed with steadily increasing momentum and importance. Moreover, twenty-six of the leading industrial laboratories of the

country have contributed about $25,000 to the association for the purchase and furnishing of the property where the conferences are held. It consists of 3.6 wooded acres with a commodious residence providing living quarters for a large fraction of those admitted to the conferences. The remainder live at the Club and all take their meals at the Club.

The association appoints a Policy Committee on the conferences, consisting of Dr. Gordon, director of the conferences, the chairmen and vice chairmen of the conferences for the year, and a representative of each of the contributing companies. Thus the initiator of the conferences, those who are primarily responsible for the programs and those whose financial support has placed the project on a permanent basis are advancing science in a way that will possibly offer a pattern for somewhat similar conferences on other fields. On the recommendation of the Policy Committee the Association appropriately named the building in which the conferences are held, in honor of their originator and guiding spirit, the Neil E. Gordon House.

F. R. Moulton

NATIVES OF NEW CALEDONIA

The occupation of New Caledonia by United States armed forces brings Americans in contact with people little known even by the ethnologist, according to a recent report of the Smithsonian Institution, whose collections throw some light on the strange ways of the life of its inhabitants. The island is one of the richest and most prosperous of the French possessions in the Pacific and is located off the eastern shore of Australia.

The native of New Caledonia is a curious mixture, both in physical characters and culture, of the black, small-statured, primitive Melanesian and the brown, robust, relatively advanced Polynesian of the Maori type. The basic stock undoubtedly is Melanesian. The island, discovered by Captain James Cook in 1774, lies well within the area of these dark little people, who include some of the least advanced of the human race. The Polynesian mixture, however, came long before the first white contacts.

Up to the time of white colonization there was little cohesion among the New Caledonian natives; in 1930 there were vestiges of at least twenty different languages spoken among them. Most of these were much more distinctive than dialects of a common basic tongue. The differentiation of the tribes was aided by the geography of New Caledonia, split by a range of high mountains with many spurs extending nearly to the coasts. These formed deep, fertile valleys through which swift rivers ran seaward. This led not only to separation, but to hostility among the different groups. Much of this now has been broken down, and the languages themselves are disappearing into an extremely degenerate French.

The characteristic dwelling is a beehive-shaped, grass-covered hut usually occupied by a single family. In economic dealings with each other New Caledonians still use a curious type of shell money consisting of shells ground down laboriously to form small globules. The value of a piece is determined largely by the amount of labor which goes into its preparation.

Each village has its own protecting divinity whose dwelling is well known—a large, fantastically-shaped stone or some other prominent natural object.

Notable curiosities of the island are the stone works, found especially on the east coast. There are stone walls which may have been intended as fortifications. There are also grotesque carvings of animals, trees and gigantic human forms which recall vaguely the statues of Easter Island. This art almost unquestionably was brought in by Polynesian invaders.

J. W. H.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1942

FOSSIL FORESTS OF THE GREAT COAL AGE

By Dr. RAYMOND E. JANSSEN

GEOLOGIST, EVANSTON, ILLINOIS

A knowledge of the past, however imperfect, adds to the attractiveness of the present.—*A. C. Seward.*

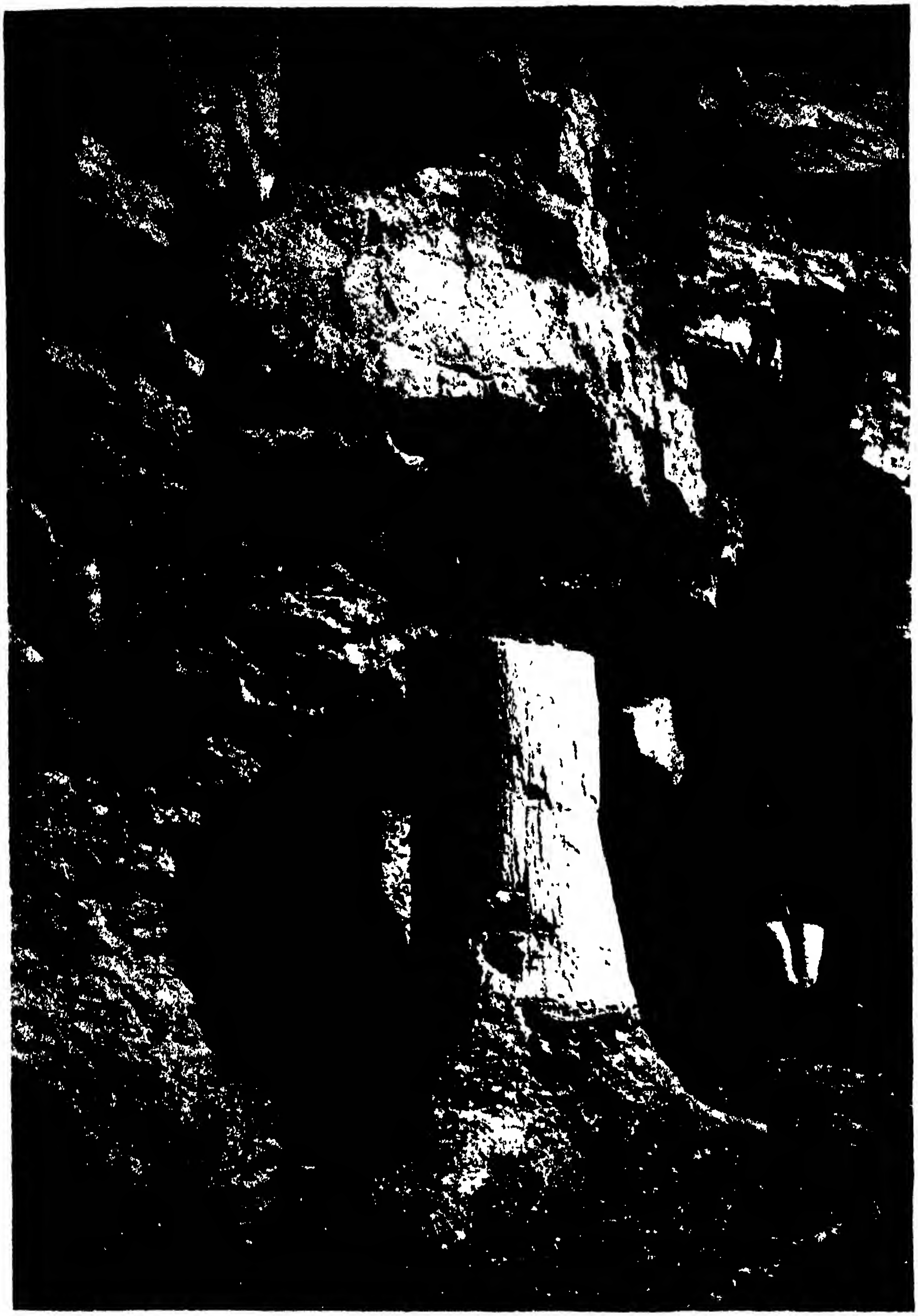
NEXT to soil and water, coal still remains the world's most vital natural resource. It was coal which made possible the melting of iron and its refinement into steel because its burning produced a hotter fire than man had ever been able to kindle before. Thus, by the use of coal, man made iron his slave, converting a medieval world into a modern one. But the use of coal for fuel was only preliminary to much wider uses. It has become the raw material from which a thousand products are made.

Coal has made possible mechanical refrigeration; thus it supplies us with both heat and cold. Coal gives us numerous kinds of plastics, chemicals and dyes, as well as sweetly smelling perfumes, flavoring extracts and sturdy fabrics. It is used for the manufacture of dynamite and ammunition, disinfectants and synthetic gasoline. Perhaps most important of all is its use as a source of medicines,

Field Museum of Natural History

FIG. 1. A FOREST OF THE GREAT COAL AGE

AS RECONSTRUCTED AT THE FIELD MUSEUM. THE PRINCIPAL TREES ARE *Sigillarias*, WITH VERTICAL ROWS OF BARK PATTERNS, AND *Lepidodendrons*, WITH DIAMOND-SHAPED BARK PATTERNS. AT THE UPPER LEFT CORNER ARE SEEN THE CONE-BEARING BRANCHES OF *Lepidodendron*. AT THE RIGHT ARE HUGE, JOINT-STEMMED *Calamites* RUSHES.



Geological Survey of Canada

FIG. 2. A FOSSIL TREE TRUNK IN A COAL FIELD OF NOVA SCOTIA.

HERE AN ENTIRE FOREST WAS FLOODED BY THE SEA, BURYING THE TREES UNDER DEEP SEDIMENTS AND PRESERVING THEM AS COAL AND FOSSILS.

particularly the new family of "sulfa" drugs—miracle drugs for the prevention of infection and the curing of diseases. The wonders which these drugs performed upon the wounded at Pearl Harbor is an epic which will long live in the annals of modern medicine.

The importance of coal in our modern civilization caused the eyes of science to be directed toward the manner of its origin. It has long been recognized that coal consists of the metamorphosed remains of plants that lived in past ages. It has been established, too, that these plants grew in great swamp forests of luxurious tropical vegetation, covering vast areas of the earth's surface (Fig. 1). Strangely, most of these ancient tropical coal forests seem to have grown in latitudes which to-day have temperate, sub-arctic and arctic climates. Over half of the world's known deposits occur within the boundaries of the United States. Europe and Asia, too, have large supplies. It is more puzzling, however, to account for the vast deposits in Alaska, Siberia, Greenland and Antarctica, great areas of which are perpetually covered with ice and snow.

But the scientist is not content to accept these facts merely as so much information. Knowledge once gained is an ever-continuing incentive toward the accumulation of further knowledge. It is desirable to know what sort of plants comprised those ancient forests and how they were able to grow luxuriously in regions which to-day support such vastly different kinds of vegetation or practically none at all.

Coal has been deposited in various quantities ever since land plants began to flourish upon the earth. But the most important of these coal beds were formed

Museum of Science and Industry, Chicago

FIG. 3. THE PLANT ORIGIN OF COAL

VIVIDLY DISPLAYED BY THIS EXHIBIT AT THE MUSEUM OF SCIENCE AND INDUSTRY IN CHICAGO. AN ENTIRE SECTION OF A STRATUM OVERLYING A COAL BED IN SOUTHERN ILLINOIS HAS BEEN EXCAVATED TO SHOW ITS CONTENTS OF FOSSIL TREE STUMPS, STEMS AND LEAVES.

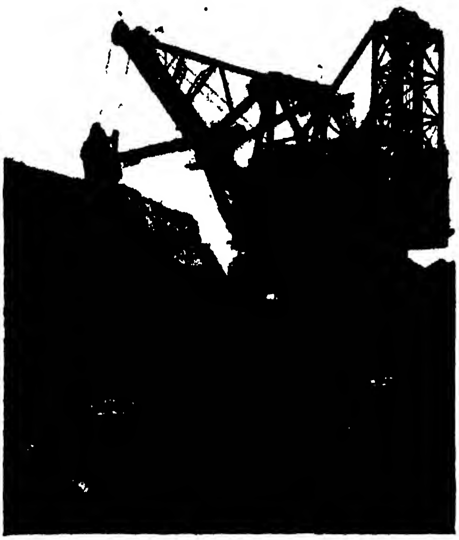


FIG. 4. HUGE ELECTRIC SHOVELS OPERATING IN MODERN STRIP MINES, INVITE THE FOSSIL COLLECTOR TO FOLLOW IN THEIR WAKE. IN THESE STRATA ARE FOUND THE PLANT REMAINS OF ANCIENT, TROPICAL FORESTS.

during the Carboniferous period of the earth's history or, more specifically, during the Pennsylvanian subdivision of this period. The Pennsylvanian period began about a quarter of a billion years ago and lasted for thirty-five million years. Throughout this long period of time, the sun's rays showered down the energy which became entombed in our wide-spread coal fields, providing the material for a more abundant life to-day.

George Langford

FIG. 5. ROOT OF A COAL AGE TREE. KNOWN AS *Stigmaria* AND ONCE THOUGHT TO BE THE STEM OF A PECULIAR TREE. SUCH FOSSILS ARE NOW KNOWN TO REPRESENT ROOT SECTIONS OF VARIOUS KINDS OF TREES. THE ROUND SCARS ARE ATTACHMENT PLACES OF FORMER ROOTLETS.

Because coal is a sedimentary rock having its origin in the plant life of another age, it follows that the study of coal should tell us much about the kinds of plants which formed it. However, the plant remains constituting the actual coal itself usually have been so squeezed and altered that their details are only partially recognizable. To a certain extent, the cell structure and reproductive spores of these ancient plants can be studied in thin sections of coal under the microscope. On the other hand, the remains which exist as fossils in the strata immediately above or below the coal beds are often so well preserved that complete leaves, with their intricate veins and texture, can be seen and studied.

The underlying beds of shale represent the former soil in which these plants grew. Commonly their roots, and sometimes upright trunks, are preserved just as they existed in the ancient soils (Fig. 2). The strata overlying the coal beds represent the sediments which were deposited above the plants during times of flood, killing and burying them, but preserving their remains as coal and fossils (Fig. 3). In these shale layers the individual plant parts have been more or less isolated and enclosed by protecting deposits of sediment. When excavated, the shaly layers reveal the entombed fossils in a perfect state of preservation.

In northeastern Illinois, particularly in the area southwest of Joliet, a coal seam lies close to the surface, and peculiar conditions of mineralization have preserved the fossils in an unusual state. Here the shale immediately surrounding

each individual fossil has become harder than the general mass of sediments, forming rounded or egg-shaped nodules or concretions. When given a violent blow with the hammer, these nodules readily split into two halves, revealing the enclosed fossil which formed a natural line of weakness through the stone. These concretions vary in size from a fraction of an inch to a foot or more in length. Usually a complete unit of a plant is exposed to view when a concretion is split open.

The usual method of obtaining such fossils is by collecting these concretions from the shale heaps following coal-mining operations. The comparatively new method of "strip" mining has resulted in the accumulation of vast heaps of such nodule-containing shale over wide areas in the mining districts. The mining itself is done by means of enormous electric shovels (Fig. 4). First the shale, averaging from twenty to sixty feet in depth, is scooped away from over the coal bed, exposing it to view. The coal is then scooped up and loaded into railway cars. The shale, which is shoveled aside in high piles, contains the fossiliferous concretions. Having thus been loosened from the general mass of sediments, the concretions are gathered from the dump heaps by the geologist who cracks them open and examines them for fossil contents. Because of this unusual occurrence of fossils here, this area, known as the Mazon Creek region of Illinois, has been more thoroughly studied for coal plant fossils than any other area of such limited extent in the world.

When dealing with living plants, the scientist can study all their parts together; but when working with fossils, it is very unusual to find complete plants. The stems, roots, leaves and reproductive organs are generally isolated and separated from each other. Since it is sometimes impossible to piece these parts together and arrive at a reconstruction of the whole, the practice has necessarily arisen of giving distinct generic names to the various plant parts. Thus organs with different names may really have belonged to the same plant. Similarly, a genus may also include remains which appear identical, but actually belonged to different plants. For example, the genus *Stigmaria* was established early in the nineteenth century by the French paleobotanist, Brongniart, for a commonly occurring stem-like fossil charac-

FIG. 6. COMMON MULBERRY TWIG CARRYING LEAVES OF DIVERSIFIED SHAPES, ILLUSTRATES THE PROBLEMS OF THE PALEOBOTANIST WHO ATTEMPTS TO RECONSTRUCT AND CLASSIFY PREHISTORIC PLANTS FROM THE WIDELY SCATTERED FRAGMENTS FOUND IN ANCIENT STRATA.

terized by numerous rounded scars upon its surface (Fig. 5). He presumed that the fossil represented the stem of a distinct type of tree and that the scars marked the attachment places of fallen leaves. It was not until the latter part of the century that specimens were discovered which revealed that *Stigmaria* was not the stem of a distinct tree at all, but actually was the root of various

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FIG. 7. TAXONOMY PROBLEMS ARE SHOWN IN THESE SEED-FERN FOSSILS FROM MAZON CREEK, ILLINOIS. *Neuropteris flexuosa* (LOWER LEFT) IS CHARACTERIZED BY A RELATIVELY LARGE TERMINAL LEAFLET. *Neuropteris gigantea* (LOWER RIGHT) HAS A RELATIVELY SMALL TERMINAL LEAFLET. OTHER CHARACTERISTICS OF THE TWO FORMS ARE SIMILAR. FOR MORE THAN A CENTURY, THESE TWO COMMON COAL AGE FORMS HAVE BEEN RECOGNIZED AS DISTINCT SPECIES. THE LARGE SPECIMEN AT THE TOP, WHICH SHOWS A PORTION OF AN ENTIRE FROND, WAS ONLY RECENTLY DISCOVERED. TENTATIVELY NAMED *Neuropteris flexantea*, IT INDICATES THAT THE TWO PREVIOUSLY KNOWN SPECIES MAY HAVE BELONGED TO THE SAME PLANT.

genera of trees. Its surface scars marked the location of former rootlets, and not leaves, as originally thought.

An interesting analogy exists in the living mulberry which may bear as many as a half dozen varied forms of leaves upon the same twig (Fig. 6). If such leaves were found separately as fossils, they might well be considered as different species, and only the finding of an entire stem with the several leaf forms attached would establish them as actually belonging to the same plant.

As the study of fossil plants continues, rare specimens are discovered from time to time which settle such pertinent points. In many respects, the work of the paleobotanist is thus made all the more fascinating, for he never knows when the blow of his hammer may uncover a specimen which will settle a century-old problem or reveal a new type which has never before been seen by human eyes (Fig. 7). Thus new light is constantly being shed upon the course which plants have followed in their evolution from the lower forms of the past to the more complex forms of the present.

When we survey all that is known of the geological history of our earth, it is difficult to realize that comparatively little was known on this subject more

than a few generations ago. Geology, as a science, had not yet come into existence; and its subdivision, paleobotany, is much younger. The foundations of scientific paleobotany were laid in Germany in 1801 by Ernst Fredrich, Baron von Schlotheim. Although the occurrence of petrified wood and leaf impressions had been noted by a few earlier writers, Schlotheim's works are the earliest scientific records known in paleobotany. His work was followed by that of Sternberg, Brongniart, Lindley, Hutton, Goeppert and Schimper, all of whom were Europeans, whose studies of plant fossils were published between 1820 and 1884.

The earliest known plant fossils from America were obtained by Ebenezer Granger in 1821 from the coal fields of Ohio. The first work of consequence to be accomplished in North American

FIG. 8. BARK PATTERN
OF *Lepidodendron* WITH CHARACTERISTIC DIAMOND-SHAPED SCARS LEFT BY FALLEN LEAVES. THESE SCARS CONTINUED TO GROW DURING THE LIFE OF THE TREE, EVEN THOUGH THE LEAVES THEMSELVES HAD FALLEN.

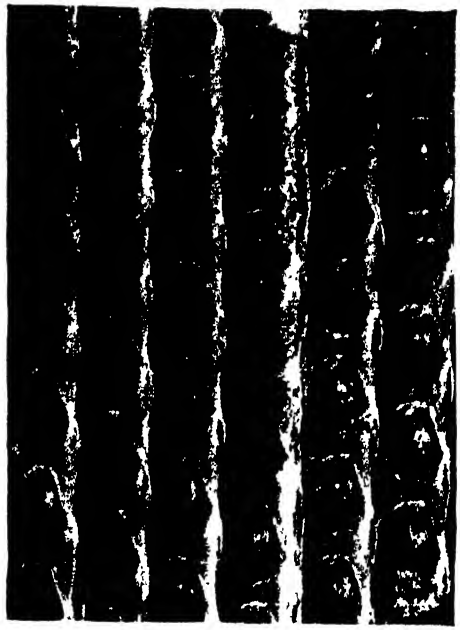

FIG. 9. BARK PATTERN
OF *Sigillaria* IS CHARACTERIZED BY LONGITUDINAL ROWS OF OVAL-HEXAGONAL SCARS, MARKING THE FORMER POSITIONS OF FALLEN LEAVES.

paleobotany was done in Nova Scotia by Sir William Dawson, beginning in 1845. Contemporaneously, work was done in the United States by Leo Lesquereux, a native of Switzerland, who had emigrated to America. After his arrival here, he became associated as a paleobotanist with numerous state and territorial geological surveys which were then being organized from time to time. Most prominent among his works were the studies of the coal flora of Pennsylvania and Illinois, the results of which appeared between 1858 and 1880. His work was followed by that of David White, late of the U. S. Geological Survey, whose publications on the coal flora of Missouri, issued between 1893 and 1899, are particularly noteworthy.

These foundations in paleobotany have been intensely broadened since the turn of the present century by recent paleobotanists. As a result, knowledge of the ancient vegetation which clothed our

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FIG. 10. A *SIGILLARIA* TREE

AS RECONSTRUCTED AT THE FIELD MUSEUM. THESE CLUB-MOSSES ATTAINED HEIGHTS OF MORE THAN 100 FEET, OFTEN SIX FEET IN DIAMETER.

earth during the great coal age has become amazingly complete.

Reconstructions of the coal age landscape show us scenes that were vastly different from those of to-day. There were no woodlands of deciduous, broad-leaved trees nor waving, grassy prairies. No pine trees clothed the hillsides, and no brightly hued flowers added color to the forests. Such plants as these were not destined to make their appearance until millions of years later. Instead, vast swamplands covered much of the earth's surface, in which flourished species of trees and plants which have long since become extinct.

The plant life, although very abundant consisted entirely of lower plant orders, such as are represented to-day by club-mosses, horsetails and ferns. Although being lower forms botanically, many of them were giants in size. The coal forests were dominated by great pteridophytes and primitive gymnosperms which attained the dimensions of our larger present-day trees. The undergrowth consisted mostly of ferns and other plants which bore fern-like foliage.

The principal trees of the coal age forests were members of the order *Lycopodiales*. This order, during the coal age, included a much larger, more numerous and more highly differentiated variety of forms than it does to-day. The majority of living members are found as small terrestrial plants or as epiphytes in moist tropical regions. A few species, found in temperate regions, are represented by the genera *Selaginella*, a club-moss, and *Lycopodium*, a diminutive ground-pine used in the making of Christmas decorations.

During the coal age, however, the lycopods were mostly arborescent forms equal to, or exceeding in size, the average forest trees of to-day. Dominant among them were the *Lepidodendron* trees, characterized by diamond-shaped, spirally arranged scars on their trunks (Fig. 8), and the *Sigillaria* trees, with vertical rows of oval scars (Fig. 9). These unusual scar patterns represent the points of attachment of fallen leaves. A peculiar characteristic of this tree bark was the continued growth of the leaf scars, even though the leaves had long since fallen off. The leaves were long and grass-like in appearance and

were clustered around the growing tips of the stems. As the stems grew, new leaves appeared at the tips, and the lower leaves fell off.

The *Lepidodendrons* branched dichotomously, that is, by twos—each branch dividing into two smaller ones again and again to the ultimate tips. At the tips were the reproductive organs or spore-bearing cones (Fig. 1). These cones were shed at intervals when ripe, the branches then dichotomized at this point, forming two new branchlets, at the tips of which a new series of cones developed. It is believed that fertilization took place upon the damp, swampy ground.

The *Sigillaria* trees seldom branched. Usually they bore their leaves in a single, spreading crown, much after the fashion of modern palm trees (Fig. 10). Their cones were produced on small stems which emerged directly from the trunks in a manner somewhat similar to the pod-bearing structures of present-day *cacao* trees.

The lycopod trees attained heights of a hundred feet or more, with diameters up to six feet. They were extremely abundant, had a world-wide distribution, and constituted an important element in the formation of coal. Some coals, such as cannel coals, seem to be

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FIG. 11. SMALL *CORDAITES* TREE AS RECONSTRUCTED AT THE FIELD MUSEUM. THESE TREES, CHARACTERIZED BY LARGE, STRAP-LIKE LEAVES, AND BEARING SMALL WINGED SEEDS, WERE EARLY MEMBERS OF THE *Gymnosperm* ORDER WHICH INCLUDES THE MODERN PINE TREE.

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FIG. 12. A FOSSIL BRANCH OF *CALAMITES* SHOWING WHORLS OF SPATULATE LEAVES ARRANGED ALONG THE STEMS OF THESE GIANT RUSHES.

made up largely of the spores of these trees.

In addition to the various forms of lycopod trees, the coal age landscape contained gymnospermous trees of the higher order, *Cordaitales* (Fig. 11). These trees were less common than the lycopods, but nevertheless were widely distributed. In some foreign regions, they seem to have constituted locally the dominant tree growth. Individuals attained, or even exceeded, heights of a

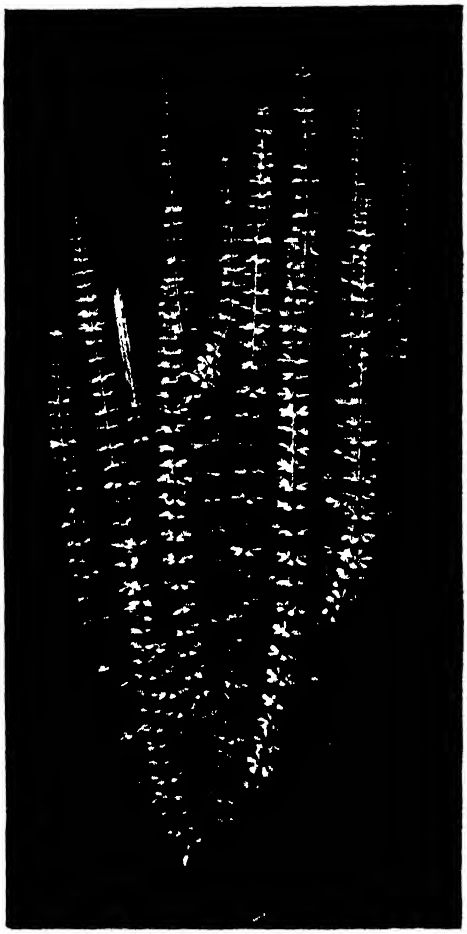

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FIG. 13. A SMALL HERB (*Sphenophyllum*) OF THE COAL AGE, AS RECONSTRUCTED AT THE FIELD MUSEUM. GROWING ABOUT TWO FEET HIGH, THIS PLANT FURNISHED MUCH UNDERGROWTH IN CARBONIFEROUS FORESTS.

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FIG. 14. AMAZON CREEK NODULE CONTAINING A PORTION OF THE STEM OF *Sphenophyllum*. IN LIFE, THIS SPECIES CONTAINED SIX WEDGE-SHAPED LEAVES IN EACH WHORL.

hundred feet, but did not exceed diameters of two feet. The *Cordaites* trees branched much in the fashion of modern trees, but bore large, strap-like leaves, spirally arranged around the stems. The reproductive organs consisted of male and female catkins borne on the branches. The female, or ovulate, catkins produced round, flattened and frequently winged, seeds somewhat resembling those of present-day elms and maples. It is believed that these trees grew in the highlands, away from the coal swamps proper. Inferences in this respect are taken from the fact that *Cordaites* leaves are found widely scattered, suggesting that they may have drifted down the streams to become buried and preserved, while the tree

trunks, which are quite rare as fossils, may have died and decayed on the uplands.

The banks of the ponds, lakes and watercourses of the ancient lowland forests were lined with dense growths of gigantic rushes, called *Calamites* (Figs. 1 and 12). They commonly attained heights of fifty feet, equalling the modern bamboo in size. The stems were jointed at intervals along their lengths, some types bearing lateral branches at all these joints, and others having branches only at widely separated joints. The leaves were borne in whorls entirely around the stems, and in groups of six to twenty or more. The reproductive spores were borne in cones at the tips of the stems. Although the gigantic *Calamites* have long since become extinct, they are represented to-day by a small descendant, *Equisetum,* commonly known as the horsetail, scouring-rush or jointed-grass, which grows as a weed in moist localities and roadside ditches. The growth of secondary wood in the trunks of the ancient *Calamites* enabled them to become sturdy, tree-like forms very different from the modern *Equisetum,* which has no secondary thickening.

Growing amid the gigantic forms of the coal age forests was a small, herbaceous plant, called *Sphenophyllum* (Figs. 13 and 14). This plant, which seldom exceeded two feet, had a slender, branching stem bearing whorls of wedge-shaped leaves. In appearance, it resembled somewhat the modern bedstraw or goose-grass (*Galium aparine*), but actually the two have no relationship. The leaves of *Sphenophyllum* were attached around the stems in multiples of three, with six, nine or twelve being the average number per whorl in most species. The reproductive spores were borne in cones at the tips of the branches and were similar in general aspect to those of the much larger *Calamites.*

Fossil impressions of fern leaves in the strata of the coal age are scarcely distinguishable in appearance from the finely divided fronds of modern ferns. Until quite recently these plants were all re-

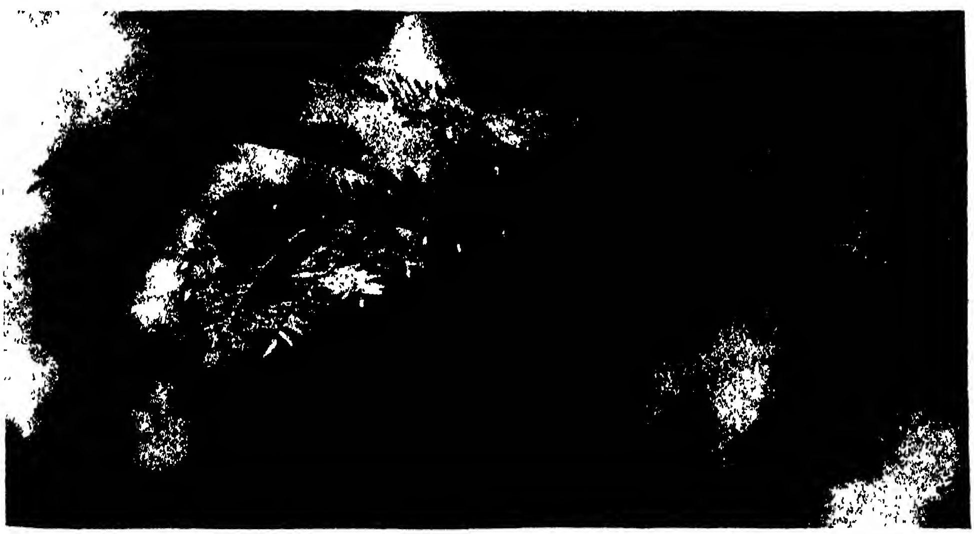

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FIG. 15. RECONSTRUCTION OF A SEED-FERN.

THE NUT-LIKE SEEDS WERE USUALLY BORNE AT THE TIPS OF THE LEAF SEGMENTS, BUT OCCASIONALLY THEY WERE AT OTHER POINTS ALONG THE RACHIS.

garded as true ferns. Because of their abundance, the coal period was commonly called the Age of Ferns.

Modern research, however, has shown that the stem structure of many of these so-called ferns differed from that of any living ferns, and, more recently, fossils have been found showing seeds attached to the fronds. This is in marked contrast to all present-day ferns, which reproduce by means of spores borne on the under sides of the leaflets. These fossil plants have therefore been placed in a distinct order, called *Cycadofilicales* by American poleobotanists and *Pteridospermeae* in Europe. Popularly, they are simply called seed-ferns (Fig. 15).

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FIG. 16. SMALL TRUE TREE-FERN

AS RECONSTRUCTED AT THE FIELD MUSEUM. SUCH TREE-FERNS WERE QUITE SIMILAR TO THOSE OF PRESENT-DAY TROPICAL REGIONS.

Some of these coal age plants were true ferns, however, but they occupied a subordinate position to the seed-ferns and can not be distinguished from them except when the reproductive organs or sufficiently preserved stem structure is found in association with the leaves. Both groups included herbaceous forms with habits similar to modern ferns. Other forms were scramblers or vines, and still others were trees reaching heights of seventy feet and trunk diameters of two feet or more (Fig. 16). These tree ferns were not vastly different from those of our present-day tropics, except that some were larger and some bore seeds. The seed-ferns became extinct shortly after the close of the coal age, but true ferns have continued to live through all the succeeding changes of the earth's geologic history down to the present time.

Many species of fern-like leaves, occurring as fossils, can not be placed, as yet, in their correct botanical positions because reproductive organs or stems with diagnostic features have not been found in association with them. Hence it is not known whether many of them were true ferns or seed-ferns.

Many kinds of nut-like seeds are found in the coal age strata (Figs. 17 to 19). They usually occur detached, but it is now known that they belonged to the seed-ferns. Very few, however, have actually been found attached to the fern fronds; hence, only in exceptional cases is it known to what species of seed-fern particular seeds belonged. Seeds attached to identifiable stems or leaves are so rare that the finding of such a specimen is usually of considerable scientific importance. Such specimens found by laymen should be immediately turned over to specialists in this field for detailed study.

The story told by plant fossils adds an important bit to our knowledge of the earth's long, eventful history. Plants now insignificant and few in number, such as the ground-pine, are found to

be the descendants of a long line of stately ancestors which formed the dominant growth of primeval forests. Others, like the seed-ferns, have left no descendants whatever. Still others, the true ferns, were able to hold their own through the succeeding ages and have come down to us in an unbroken line. Although numerous attempts have been made to explain such riddles, we can only speculate vaguely, as yet, upon the causes of success or failure which have determined such events.

The flora of the great coal age compares more approximately with that of our present tropics than with any other. The trees of the Carboniferous period do not exhibit annual growth rings in

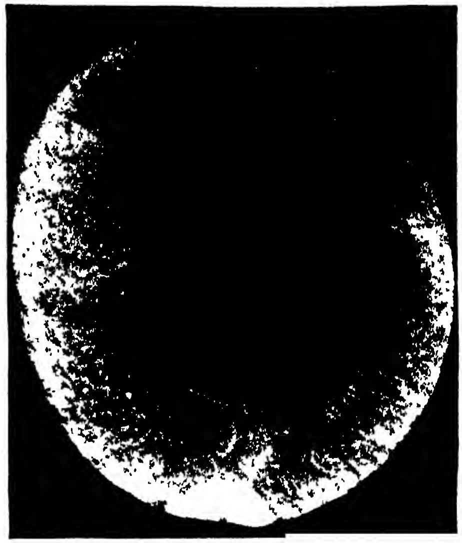

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FIG. 18. ANOTHER NUT-LIKE SEED (*Holcospermum*) BORNE BY CERTAIN SEED-FERNS, HAD NUMEROUS LONGITUDINAL RIBS AND GROOVES ON ITS HUSK. THIS EXTERIOR HUSK WAS ABOUT TWO INCHES LONG; THE ENCLOSED NUT ITSELF BEING FROM ONE-HALF TO ONE INCH LONG.

Illinois State Geological Survey

FIG. 17. A FOSSIL SEED OF THE TYPE BORNE BY THE SEED-FERN SHOWN IN FIG. 15. SUCH SEEDS, CLASSIFIED UNDER THE GENERIC NAME, *Trigonocarpus*, VARIED IN LENGTH FROM THREE QUARTERS OF AN INCH TO TWO INCHES. THE SHELL WAS DIVIDED LONGITUDINALLY INTO THREE EQUAL VALVES, MARKED BY PROMINENT RIDGES AT THE SUTURE LINES.

their stems, and this also is an indication of more or less uniform growing conditions uninterrupted by seasonal fluctuations. This situation excites the interest of scientists because the greatest coal deposits are situated in the northern hemisphere and within the temperate and arctic zones. From this evidence it would seem that a warm, uniform climate must have then existed over nearly all the earth's surface.

Such a condition would very well account for the finding of plant fossils and coal beds in the arctic and antarctic regions. Unfortunately, however, the problem is not so easily answered. In addition to a favorable climate, plants also require an abundance of sunlight for luxuriant growth. The explanation has failed to show how the coal-forming plants could have received sufficient sunshine to have grown continuously, without showing even an indication of

FIG. 19. FOSSIL SEED
Carpolithus noéi, JUST RECENTLY DISCOVERED, HAS NUMEROUS BLUNT, IRREGULAR SPINES UPON ITS SURFACE. ALTHOUGH ITS AFFINITY IS NOT YET KNOWN, IT IS PROBABLY THE FRUIT OF A SPECIES OF SEED-FERN.

seasonal growth rings, in latitudes where the polar nights are several months long.

An attempt to explain this riddle was made a few years ago by the German scientist, Alfred Wegener, and has been further advanced by a few other scientists. This theory, called the Continental Drift Theory, suggests that the continents were once part of a single larger continent which existed in more central latitudes where luxuriant plant life was possible. The great continent is represented as having floated on a plastic substratum. Then, at a more recent time, this hypothetical continent broke into several sections which drifted apart to become the separate continents and land masses as we know them to-day.

This theory, which radically opposes previous conceptions of the stability of continental masses, has not met with a uniformly favorable reception among geologists. However, nothing else so well explains the wide distribution of the tropical vegetation of the great coal age. Only time and continued research will ultimately tell whether or not the theory has practical merit.

Unfortunately, the world is now engaged in a mighty conflict, and many of the scientists who have been engaged with the solutions of such problems have been called to more immediate and urgent research. But eventually, in a free world, there shall again be ample opportunity for the consideration of such age-old problems. Although frequently interrupted and delayed, the work of the scientist is never finished—for he never knows when some bit of evidence, newly discovered or previously considered unimportant, may furnish the clue to a more thorough understanding of the profound changes which have affected our earth and the evolution of life upon it.

ANCIENT IRRIGATION IN CHINA BROUGHT UP TO DATE

By Dr. W. C. LOWDERMILK and Dr. D. R. WICKES

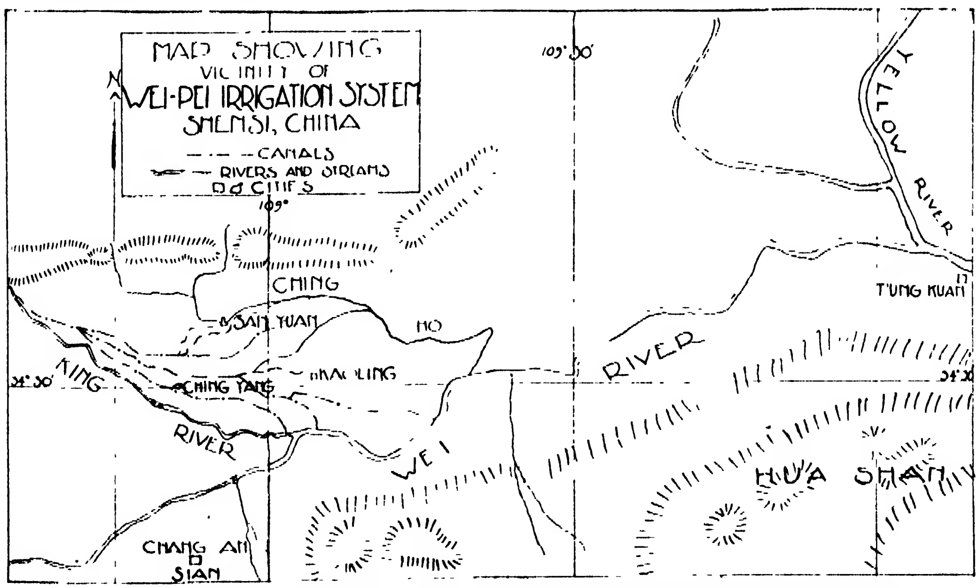
SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

Of irrigation works constructed in China with the consultation of American engineers, the most interesting project has recently been brought to completion in the alluvial plain of the Wei River. This project was under study by Mr. Li Hsieh, a Chinese conservancy engineer, who showed O. J. Todd, chief engineer of the International Famine Relief Commission, and the senior writer over the project several years ago. Since that time, the Chinese Government has completed this project, to use the available flow of the King River to its maximum capacity for irrigating land in the Wei-Pei plain.[1]

[1] O. J. Todd, *Civil Engineering*, 7: 553, August, 1937. Mr. Todd was chief engineer and Mr. Eliassen resident engineer for the intake works and upper portion of the main canal, Mr. Li Hsieh chief engineer for the rest of the project. A fuller description by S. Eliassen and O. J. Todd was published in the *China Journal*, 17: 170–180, October, 1932.

The Wei River is the principal tributary of the Yellow River, which has so long been known to the Sons of Han as "China's Sorrow." The Wei drains the northern slopes of the picturesque Tsingling range of mountains. This range, lying east-west athwart the country, is the natural great wall of China; it separates the regions of the loess to the north from regions without loess in the south and divides wheat-growing from the rice-growing areas of China. The Wei River irrigation project is one of the earliest recorded in Chinese history and has a fascinating history.

The fruitfulness of the fertile plain of the Wei River under ancient works of irrigation, which were begun more than 2,000 years ago, nourished in former times a rapidly growing population of vigorous people who established the ancient capital of Changan (Prolonged Peace). The present city of Sian in Free

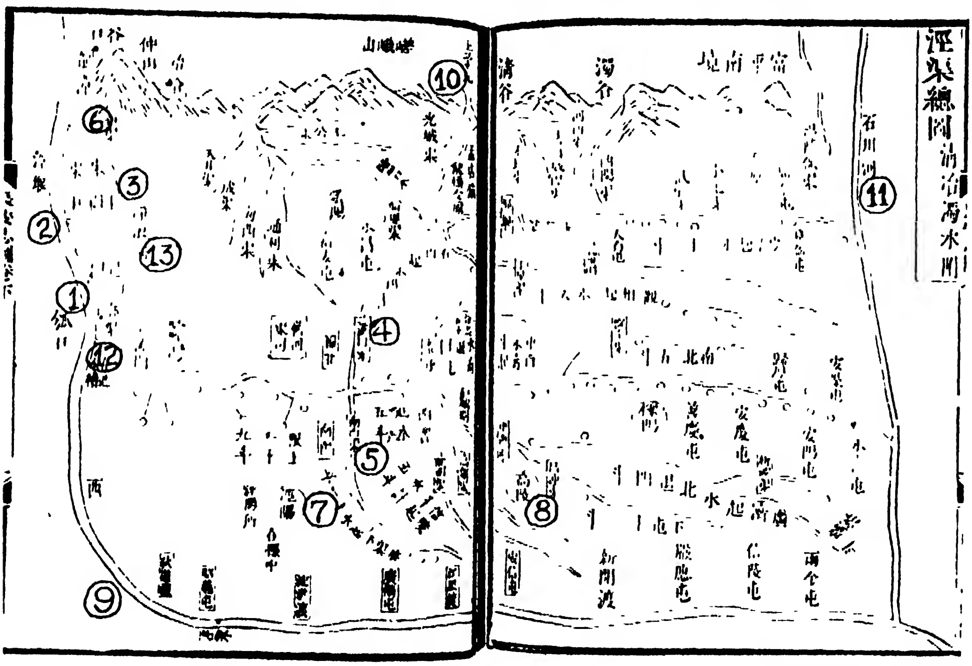


A MAP OF THE VICINITY OF THE WEI-PEI IRRIGATION SYSTEM

China now stands on the site of this ancient capital of the Chinese Empire. A paper on the Yellow River problem, by O. J. Todd, consulting engineer, and S. Eliassen, has just appeared in the *Transactions* of the American Society of Civil Engineers[2] which refers to the irrigation works recently completed to spread water again on lands where ancient works of irrigation had failed. Because the Chinese gazetteer and other records of this irrigation project go back more than 2,000 years, the detailed history of dealing with silt-laden waters has a lively interest to American conservationists, who are concerned with flood control and water supply in the new land of America. Such a long authentic record gives a background to our forecasting and preparing for problems of silt control and disposition. The junior author has consulted the splendid library in the Chinese language which has been collected in the Library of Congress and has translated these records going back more than 2,000 years. From field surveys of the Wei-Pei project and from these accounts is drawn the material for this paper.

The history of the valley of the Wei River and its irrigation is to be found scattered in numerous Chinese works, of which some go back to the early years of the Christian era, and others were written at intervals by Chinese historians down to the present time. A study of this literature reveals a fascinating story of great efforts made at many different times to maintain a large and vigorous population in this region of what is now "Free China."

[2] Vol. 105, p. 346, 1940.



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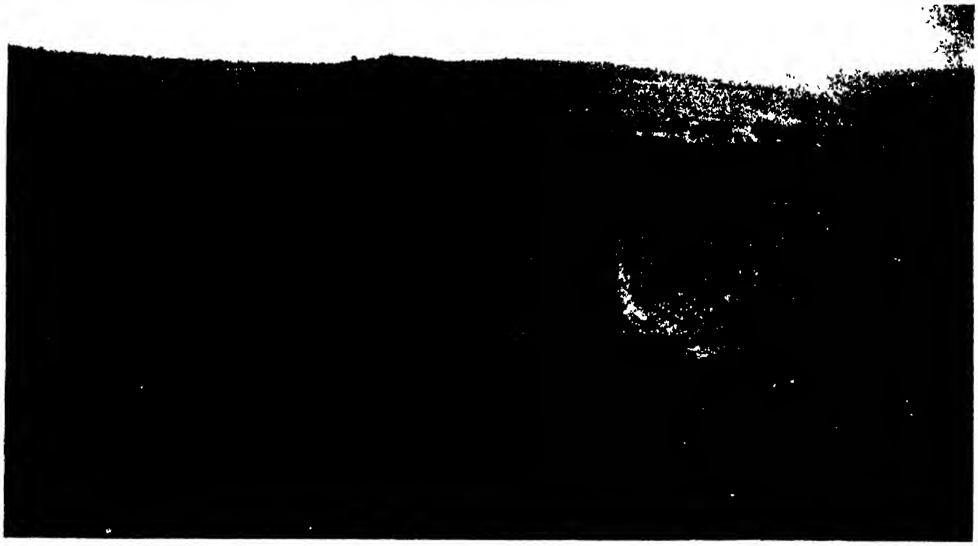
OLD CHINESE MAP FROM GAZETTEER OF CH'ANG-AN DATED IN 1784

SHOWING CANALS FROM THE KING RIVER, WITH CANALS FROM SMALLER STREAMS IN NORTHERN PART. (1) INTAKE OF CHENG CANAL (THE EARLIEST RECORDED); (2) INTAKE OF PAI CANAL (THE SECOND RECORDED); (3) SUNG DYNASTY CANAL; (4) AND (5) GREAT PAI AND SOUTH PAI CANALS; (6) ROCK-CUT CANAL; (7) CHING YANG CITY; (8) KAO LING CITY; (9) KING RIVER; (10) CH'ING VALLEY; (11) SHIH CH'UAN HO RIVER; (12) ANCIENT OVERFLOW CHANNEL; (13) OVERFLOW CANAL.



SITE OF THE ORIGINAL INTAKE OF THE CHENG CANAL
BUILT IN 246 B.C. THE ENTRENCHED CHANNEL OF THE KING RIVER IS SEEN IN THE BACKGROUND. THE STREAM IS NOW ABOUT SIXTY FEET BELOW THE ORIGINAL CANAL LEVEL.*

The first recorded canal for the irrigation of this area was begun under the first Emperor of China, Ch'in Shih Huang, in his first year as King of Ch'in, 246 B.C., a few years before he became Emperor.[3] The area is a broad plain of alluvium and loess which was deposited in an ancient lake basin by water and by wind. The Wei River with a few tributaries, of which the King River is the principal one, flows through this "Cradle of Chinese civilization." The Wei-Pei irrigation project has been eleven times remade in whole or in part during the twenty centuries since that time. In addition, repairs and additions were made from time to time. All this tells of a remarkable struggle to maintain productiveness of land irrigated with silt-laden waters. It is a battle with silt for twenty centuries which was finally lost until modern power machinery and reinforced concrete construction gave a new lease on life to this famous irrigation project. Even now the total area irrigated under modern works is less than that once watered under ancient works.[4]

This age-old irrigation system has played an important role in the history of China. For centuries it made the region in which it lay the key economic area of China, supporting a population that was able to control the rest of the country.[5] As the old record puts it: "Thereupon Kuanchung became fertile territory without bad years; whereupon Ch'in became rich and powerful and finally conquered the feudal princes."[6]

It is recorded that in the early period

[3] Ch'ao-ting Chi, "Key Economic Areas in Chinese History," 1936, p. 75 *ff*.

* Photographs by O. T. Todd and senior author.

[4] 100,000 acres in 1937. O. J. Todd, *Civil Engineering*, 7: 553, August, 1937. Over 40,000 ch'ing, more than 400,000 acres at 10 mou to the acre, for the first canal system according to the Han Shu and Shih Chi historical records. *Cf.* Edouard Chavannes, "Les Memoires Historiques de Se-Ma Ts'ien, pp. 523 *ff*., 1898. For the size of the mou in the Ch'in and Han Dynasties see Mabel Ping-Hua Lee, "The Economic History of China," p. 435, New York, 1921.

[5] Chi, 1936, pp. 77–80, 95.

[6] Ch'ien Han Shu, 29/5 b *ff*.

the system irrigated about 625 square miles, or 400,000 acres,[7] of salty alluvial plain to produce crops of millions of bushels of grain. Harvests of 14,500,000 bushels are reckoned as produced on the land irrigated by the first canal system alone. The average yield was about 36 bushels of wheat per acre.[8]

The maintenance of such a system was an immense task, and many and varied methods were used in the course of the two thousand and more years since it was begun. It may be inferred that removal of silt was an early and constant task, though the earliest specific mention of the necessity for this is found in a report of the year A.D. 995.[9] This report mentions the blocking of canals with silt as a thing to be yearly watched for and promptly attended to by officials in charge. Before this time the presence of silt in considerable quantities in the water used for irrigation seems to have been regarded as an advantage rather than a disadvantage by improving fertility of fields. Such an idea is expressed during a period between A.D. 649 and 659 by an official of the Emperor Kao-tsung of the T'ang dynasty.[10] An ancient Chinese song in celebration of the early canals, recorded in the history of the earlier Han dynasty[11] in A.D. 82, has the same idea. "In one stone of King water, there are several pecks of mud. Both irrigating and fertilizing, it makes long our growing millet, feeding and clothing the capital's vast multitudes."

Change in the appraisal of the value or nuisance of silt in irrigation water is also found in other projects outside of

[7] 40,000 ch'ing, see note 4.

[8] The Han Shu states that the 40,000 ch'ing of salt land when irrigated produced throughout harvests of one chung (about 3.626 bushels) per mou. *Loc. cit.*

[9] Official report quoted in History of the Sung Dynasty (Sung-Shih) 94/24 b.

[10] Quoted by K'ung Chuan, official A.D. 1131–1162, in Pai K'ung liu t'ieh 81/5b *f.* Quoted from this in Shensi T'ung chih (official gazetteer) (1735) 39/64 a.

[11] Ch'ien Han Shu, 29/12 a.*f.*

DRY CANAL OF THE WEI-PEI IRRIGATION SYSTEM

SHOWING EXCELLENT MASONRY AT HEAD WORKS OF SUBDIVISION CANALS. A BURIAL MOUND IS VISIBLE IN LEFT MIDDLE GROUND; A TEMPLE, WITH A GROVE OF TREES IN RATHER BAD CONDITION OWING TO GENERAL POVERTY OF THE REGION, MAY BE SEEN IN THE BACKGROUND; THE SENIOR WRITER STANDS BY THE CANAL.

SECTION OF THE CANAL CUT THROUGH LIMESTONE ROCK
CARRYING ONLY THE CLEAR FLOW OF GREAT SPRINGS ISSUING FROM LIMESTONE CAVERNS CUT THROUGH IN DIGGING THE CENSOR WANG CANAL IN 1314–1318 A.D., PART OF THE WEI-PEI PROJECT.

China. So long as silt consists of top soil eroded from slopes of a drainage, deposition of it on valley lands generally enhances their fertility; but when silt is derived from subsoils and sterile substrata of soils by erosion it damages land. The spread of clays upon fields in the Rio Grande Valley in the vicinity of Albuquerque[12] has done serious damage to the land. Likewise, when the material is made up of coarse sands, productivity of irrigated land may be seriously lowered, as in the Imperial Valley. In addition to its harmful effects, sterile material encumbers a project by the necessity of its removal, always at increasing costs, and in time endangers the project as the Wei-Pei Project discloses.

A report to the throne in 1343 by Sung Ping-liang[13] recommends a method used in ancient times, the closing of flood gates in time of unusually high water in the King in order to prevent the silting up of the canal. He calculated that by rebuilding such gates to be opened and closed at proper times to prevent suspended mud from entering the main canal they would decrease by half the labor of cleaning silt out of canals.

The *Gazetteer* of Chang-an for 1787[14] says: "Every year repairs are added, and the labor of men cleaning out mud and sand from the rock-cut canal, above and below, does not cease." Each family using water on its land had also every year to open and clean out canals and ditches to assure a free and uninterrupted flow.[15] Piles of silt thirty-five feet high along the banks were reported in the fourteenth century, and passageways were repeatedly excavated through these that the silt taken from the canals might be moved farther from the banks rather than placed on these mountainous piles from which it was liable to erode or slip back into the water during heavy rains.[16]

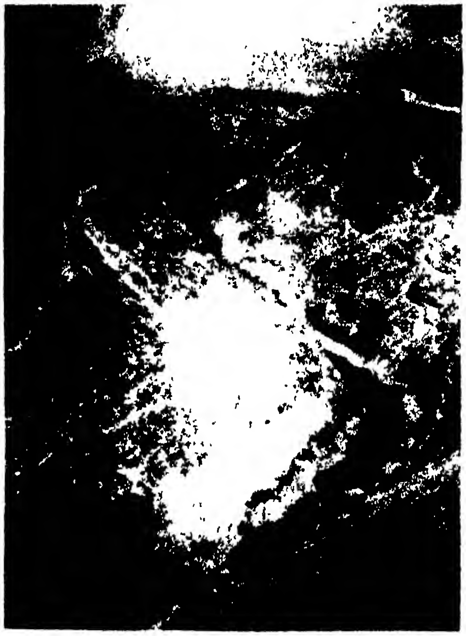
12 H. H. Bennett, *Jour. Am. Soc. Agr.*, 23: 1, June, 1931.

13 Censor in charge of Shensi circuits. Chang-an chih Atlas, hsia/19a. *f.*

14 Chang-an chih (1787) (1891 reprint) Atlas hsia/ 9 b.

15 *Id.*, hsia/12 a.

16 *Id.*/20 a; Yuan Shih 66/15 a; Ching-yang hsien chih, (1841) 13/3 b.



A SECTION OF THE CANAL
THROUGH WHICH FLOWS CLEAR WATER FROM LIMESTONE SPRINGS. THE HIGH BANKS ARE MADE UP OF SILT CLEANED OUT OF THE CANAL WHEN IT CARRIED THE MUDDY WATERS OF KING RIVER. WITHOUT POWER-DRIVEN MACHINERY FOR CLEANING THE CANAL THE IRRIGATION SYSTEM IS IN TIME PUT OUT OF COMMISSION BY SILT.

The most frequently recorded method of maintenance of this irrigation system, however, was the making of new canals obviously in part to avoid cleaning silt out of old canals. It would appear that time after time the system was largely ruined and fell into disuse, after which some leading man would take cognizance of the situation and secure the excavation of a new canal to take the place of the old in whole or in part. This occurred in 95 B.C. under Pai Kung; in A.D. 377 under Fu Chien; in 823 under Liu Jen-shih; in 958 under Hê Yu-chung; in 1006 under the Sung Emperor, Chên-tsung; in 1072 under Hou K'o; in 1108 under Chao Chuan; in 1314–1318 under Wang Chü; in 1645–87 under Hsiang Chung; in 1516–1532 under Hsiao Chung and Liu T'ien-ho; and finally in 1930–35 with the aid of the American China International Famine Relief Commission.[17]

The prime importance given to agriculture in this area is indicated by the fact that on several occasions in the Tang dynasty between A.D. 650 and 778, it is reported that mills using water from the canals built for irrigation were destroyed by Imperial order in order that the full volume of water might be used for the irrigation of crops in the plain. In A.D. 778, eighty mills were so destroyed, despite the fact that some of them belonged to a royal princess and the family of her husband.[18]

The later canals, beginning about A.D. 1072, required excavation in solid rock, which was formerly broken up by building fires upon surface rock, followed by pouring cold water over it.[19] Blasting with black powder was used in 1930–35. To raise the level of water in the river in ancient times to discharge into a canal which was then above the natural level of the river, barrages or diversion dams of different sorts were built.

References to efforts to raise the intake of the canal appear several times. The report of a commission made in A.D. 995 stated that formerly a barrage was built of stone in the river 100 paces broad, and an attempt was made to rebuild it in A.D. 991. This new effort was a barrage of wood, using over 11,300 stakes. After the irrigation for the year had been finished the dam was torn down and the wood kept for use the following year. Thirteen thousand men were re-

[17] See Ching-yang hsien chih (1841) 13/1a–4a and Appendix, 1/1a *ff.*, 3/2b–8a; Chinese Encyclopedia, 258/hui k'ao/6a *ff.*, 258/chi-shih/5b *f.*; S. Eliassen and Todd, The Wei Pei Irrigation Project in Shensi Province, *The China Journal*, 17: 170–180, 1932. O. J. Todd, *Civil Engineering*, 7: 553, 1937.

[18] Hsin T'ang Shu, 126/7a, 146/1b, quoted in the Chinese Encyclopedia 258/chi shih/3b, 4a *f.*; *Life of Li Kan*, *ibid.;* Yü-hai 22/11 a.

[19] Yuan Shih, 65/12 b.; *cf.* Chinese Encyclopedia, 258/chi shih/9 b.

quired for this operation, and were provided pro rata by those benefited, under supervision of the districts.[20] At one period shortly before A.D. 1314 bins of wicker-work filled with stones, 380 in number, were set up in the river yearly with a great amount of labor. Each bin was over 10 feet high. After the excavation of the Censor Wang Canal in 1314, 180 bins were used, in three ranks; those in the deeper parts of the river reached 15 feet in height. Every flood in the river threw them down in ruins. Holes cut into the rock held piles for the support of a Sung dynasty barrage (A.D. 960–1276). Wicker fences and barriers are reported to have been used in the Chien-teh period (963–967). These also had to be replaced yearly. An attempt to avoid this yearly expense through the building of a stone dam was given up.[21] In 996 the method used for building dams was to hold stones together by means of iron, melted and poured into the interstices.[22]

The reason for such diversion barriers became apparent in our field examination of the old canal system. We found where the original canal had taken water out of the King River. But now the river is about 60 feet below the level of the old canal. In the past 2,000 years the stream has been excavating its channel below the intake of this first canal. As the river lowered its channel barrages or barriers were placed across the stream to raise the level of river water. When this was impossible, it became necessary to dig a new canal extending the intake higher up the stream for head enough to flow into the canal. Establishing entirely new intakes of the main canal was done many times during the life of this project, as the record and field evidences show. One such new canal was extended upstream until it had to be cut through limestone rock of a gorge of the King River. But in time river erosion cut into this canal and made it useless. Still other canals were located and cut into the rock wall higher up the slope. We estimated that in places the highest canal

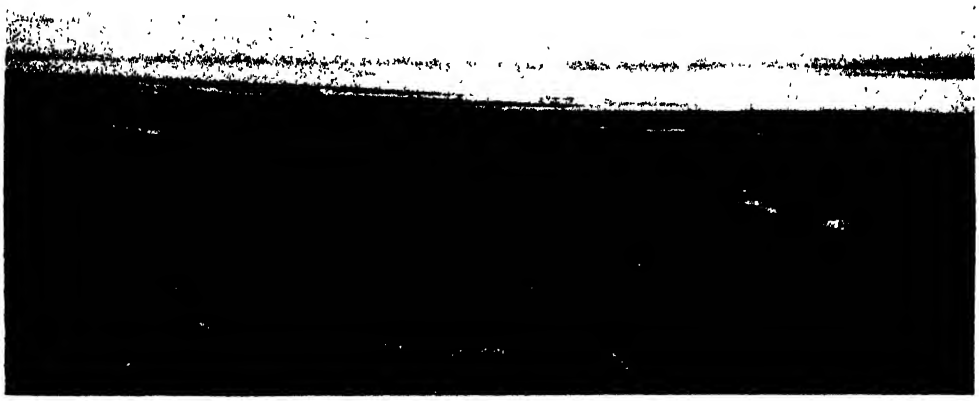
IN THE KING RIVER GORGE

INTAKE OF THE NEXT-TO-LATEST CANAL, ABANDONED BECAUSE THE HEAVY BURDEN OF SILT OF KING RIVER WATERS CHOKED UP THE CANAL SYSTEM. TODD SAMPLED THE WATER AND FOUND IT TO CONTAIN 46 PER CENT. SILT BY WEIGHT. THE SMALLER FLOW OF CLEAR WATER TAPPED BY CUTTING THE CANAL THROUGH A LIMESTONE FORMATION WAS USED FOR IRRIGATION UNTIL THE MODERN PROJECT WAS CONSTRUCTED.

[20] Ching-yang hsien chih (1841) 13/2 a.

[21] Sung Shih 94/19 a b; *cf.* Yü-hai 22/35 b, giving a report of the year 996 concerning such an attempt.

[22] Yü-hai. 22/35 b.



VIEW OF TUNG-KWAN WITH THE YELLOW RIVER IN THE BACKGROUND
THE WEI RIVER JOINS THE YELLOW RIVER NEAR TUNG-KWAN. THE TWO GIANT TOWERS, FORTIFICATIONS OF THE GATE OF THE CITY, ARE BUILT OF BURNED-BRICK. HIGH, BURNED-BRICK WALLS ENCLOSE THE CITY.

had been cut fully 100 feet into the rock. A system of excavation and tunneling was used in digging these canals, showing capable engineering in ancient times. This last canal cut through an underground channel in limestone rock, bearing a stream of water. The clear water of this spring increased the flow of river water.

And now the modern or eleventh major relocation of the canal extends the intake still farther upstream. The dam or barrage is located at a point where the canal had to be tunneled 1,500 feet through the mountain. Modern engineering has only carried out the scheme of ancient Chinese engineers; it has had, moreover, the advantage of power-driven machinery and reinforced concrete construction to build more lasting structures. In fact, at the time of our inspection we heard of a proverb of long standing in the region, that the new canal must pierce the mountain to give water to the plain.

The latest dam is of concrete, with a core of masonry, 215 feet long, designed to pass a head of 50 feet of flood water. It is 30 feet high at the maximum and has a top width of 16 feet. It has a sluice opening (two originally) for flushing the mud through it at times of flood, when the silt content of the torrential waters is very high.[23]

Torrential streams intersecting the canals were carried over them on bridges of masonry to prevent blocking with detritus. This is reported for the canal finished A.D. 1110;[24] is again referred to in the Wan-li period of the Ming dynasty (1573-1619);[25] and is one of the rules set forth early in the Ch'ing dynasty.[26] The most recent canal has 11 such structures.[27]

For the latest canal of modern construction with a tunnel 1,500 feet long, an air compressor and pneumatic drill equipment were used besides hand drilling to prepare the rock for blasting, and concrete and masonry construction were used at head gates, dam and sluice-ways. Powered equipment gave modern engineers a big advantage over ancient Chinese engineers. Honor goes to these

[23] O. J. Todd, *Civil Engineering*, 7: 554, 1937.

[24] Chang-an chih (1787) Atlas hsia/76; also in Ming ed. Shang/50 a.

[25] Ching-yang hsien chih (1841) 13/4 a.

[26] *Ibid.*

[27] Eliassen and Todd, p. 178 and illus.; China International Famine Relief Commission Report for 1931, p. 63; O. J. Todd, *Civil Engineering*, 7: 553.

Chinese engineers of the past for their ability and achievements with simple masonry and hand labor.

Why were all these efforts required, and why despite them all was the irrigation system always losing its effectiveness?

One reason has already been suggested in the high silt content of the water. The ancient song celebrating the benefits from the two first canals, found in the "History of the Earlier Han Dynasty" (completed in A.D. 82) says: In one stone (*shih*) of King water there are several pecks (*tou*) of mud.[28] The significance of this statement becomes clearer when we learn that analysis of water at the intake of the most recent canal during freshets in 1931 and 1932 showed 46 per cent. of silt by weight.[29] Modern engineers consider a 5 per cent. load safe for the canals, and have allowed water with 20 per cent. of mud to pass through to the lands, but do not recommend the practice.[30]

Protection of the Wei-Pei Canal system from excessive silt had been attempted long before 1343 by the use of head gates to be closed at proper times, as indicated in the report of Sung Pingliang in that year. By the year 1737 the recurrent damage from silt had become so serious that it was decided to exclude entirely the water of the river from the canals, and an embankment was raised for this purpose, water from springs alone being depended on for irrigation, as field evidence indicates. The area irrigated was reduced to less than one tenth of the original project. This attempt was not entirely successful, for in 1754, in 1787 and again in 1816 the river

[28] See note 11. As dry measure the tou is 1/10 of a shih. Giles, Chinese-English Dictionary, 2d ed., 1912, No. 11427.

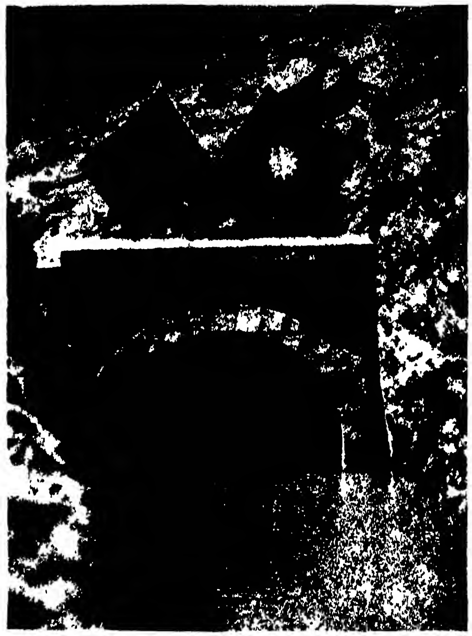
[29] Eliassen and Todd, p. 174.

[30] O. J. Todd, *Civil Engineering*, 7: 554.

VIEW OF THE MODERN DIVERSION DAM

BUILT STILL HIGHER UP THE KING RIVER GORGE THAN THE INTAKES OF ANCIENT CANALS. IT WAS POSSIBLE TO MAKE USE OF POWER MACHINERY AND REINFORCED CONCRETE TO BUILD A DURABLE STRUCTURE. BUT IT WAS NECESSARY IN THIS PROJECT TO DIVERT THE MAIN CANAL THROUGH A 1,500-FOOT TUNNEL TO GIVE IRRIGATION WATER THE HEAD NEEDED TO SUPPLY THE CANAL SYSTEM.

INTAKE GATE
OF THE 1,500-FOOT TUNNEL DIRECTING THE MUDDY KING RIVER WATER INTO THE MAIN CANAL.



OUTLET OF 1,500-FOOT TUNNEL
THE CHINESE NATIONAL FLAGS IN THE PICTURE REMAIN FROM THE OPENING DAY CEREMONIES.

broke through the barrier and silted up great lengths of canal.

On the main river and most of its branches storage is impractical because of the heavy silt loads in flood time, which would fill a reservoir in a couple of years.[31]

Another reason, apparently of even greater importance, for the repeated excavation of new canals, was the lowering of the river bed by erosion or scour, which was presumably more rapid because of the materials carried along by the water. In A.D. 1343 the censor in charge of Shensi circuits in his report to the Emperor said:

> It is found that the destruction of the value of canals in ancient and modern times is all because the river bed gradually becomes low, the mouth of the canal high, so that the water can not enter. So Pai could not but supplement the Cheng Canal, the Feng-li Canal could not but be opened after the Pai Kung Canal; and now the Feng-li canal mouth has in turn gradually become high. At present, measuring the distance of the mouth of Cheng's Canal above the surface of the water, it is found to be higher by more than 50 feet. The mouth of the Pai Kung Canal is at a height above the water level calculated as 13 feet. . . . At present the Feng-li Canal is also more than 7 feet above the water.[32]

Severe floods have many times destroyed barrages built to raise the level of water to the mouths of canals. Such was a yearly occurrence during part at least of the tenth and fourteenth centuries.[33] Floods also were responsible for silting and other injury to the canals during the period when it was attempted to exclude the river water, as already mentioned. Of recent years the maximum flood flow of the King River for rare periods has been estimated at 550,000 cubic feet per second. On the other hand, studies have shown a very

[31] Eliassen and Todd, p. 174.

[32] Quoted in Chang-an chih Atlas, hsia/17 b *f.*

[33] See above, p. 8 *f.*

low flow for short periods during January and June, with a minimum of less than 200 feet per second in January, and of 250 cubic feet per second in June, which is less than half the capacity of the present canal.[34] Some had hoped that over a million acres could be irrigated from this canal, but it has been found impossible to supply anything like that area on account of the small amount of water at critical periods and the high silt content when the water is high. An area of only 100,000 acres has recently been supplied with water, being one fourth of the area reported under irrigation in ancient times.[35]

The difference between the area now watered and that irrigated in earlier periods suggests deterioration of the regimen of the river since the early days of the Chinese Empire. While little is known historically that would furnish a basis for conclusions on this point, erosion conditions point in that direction. In the "Book of Odes," which reflects a period earlier than the earliest canals known in this region, *i.e.*, prior to 246 B.C., it is stated that the King River makes the Wei River muddy, with patches of clear water. The comment of Chu Hsi (twelfth century) states: "The waters of the King are muddy, and those of the Wei are clear, and the muddiness of the King appears more clearly after its junction with the Wei," and "The King River is muddy but not very muddy."[36] However, in recent times, the Wei has a heavy silt load, comparable to that now found in the King.[37]

Changes in the silt burden of the King and Wei Rivers as recorded in gazetteers of Chang-an, would agree with extension of farming out of the alluvial valley up slopes of the surrounding country. It is probable that agriculture first developed on an extensive scale in the alluvial val-

[34] O. J. Todd, *Civil Engineering*, 7: 554.

[35] *The Oriental Engineer*, Vol. 7, No. 3, p. 11; Eliassen and Todd, pp. 174–176; Todd, *Civil Engineering*, Vol. 7.

[36] Chinese Encyclopedia, "Mountains and Rivers," 258/hui k'ao/1 b; Legge, "The Chinese Classics," Vol. IV, Part 1, p. 56.

[37] O. J. Todd, *Civil Engineering*, 7: 556, 1937.

DIVISION OF THE MAIN CANAL INTO TWO LINES

TO SPREAD WATER AGAIN TO THE FERTILE PLAIN WHICH HAS BEEN UNDER IRRIGATION FOR MORE THAN 2,000 YEARS, BUT WITH INTERRUPTIONS DUE TO SILT CAUSED BY SPECTACULAR ACCELERATED SOIL EROSION OF THE LOESSIAL SOILS OF NORTHWEST CHINA.

AN AREA OF THE YELLOW RIVER DRAINAGE
WHERE GULLIES HAVE REACHED SPECTACULAR PROPORTIONS, ESTIMATED TO BE FULLY 500 FEET DEEP. NOTE THE REMNANTS OF TERRACING ON GULLY MARGINS SHOWING THAT LAND HAD BEEN CULTIVATED PRIOR TO HEADWARD CUTTING OF GREAT GULLIES. ALL LAND NOT TOO STEEP IS CULTIVATED.

leys. As population increased and pressure upon the land increased, the cultivation line was pushed up slopes higher and higher, as the senior writer has found reasons to believe in field studies in Shansi.[38] With clearing and cultiva-

[38] W. C. Lowdermilk, *China Jour. Sci. and Arts*, 14: 3, 1926.

A DROP ON THE NORTH BRANCH OF THE MAIN MODERN CANAL
OF THE WEI-PEI PROJECT. NOTE THE KING RIVER WATER IS THICK WITH SILT. IT IS PROPOSED TO DIVERT RIVER WATER WITH NO MORE THAN 20 PER CENT. OF SILT. THIS AMOUNT, HOWEVER, SOON CREATES SERIOUS PROBLEMS IN SILT DISPOSAL. SILT RESULTING FROM SOIL EROSION OF LOESSIAL SOILS AND BANK-CUTTING OF CURRENT DEPOSITS OF SILT IN RECEDING FLOOD FLOWS PRESENTS A PROBLEM FOR MAINTAINING IRRIGATION MORE DIFFICULT THAN ANYWHERE KNOWN BY THE AUTHORS.

tion of slopes, soil erosion was accelerated to prodigious amounts as shown by enormous gullies of recent growth in these loessial lands of northwest China. The silt burden of flood waters increased to the fabulous quantities measured by the senior writer in Shansi of 24 per cent.,[38] and by O. J. Todd in Shensi of 46 and even to 50 per cent. by weight.[39]

The Wei Valley about Chang-an (Sian) was the center of population so that the extension of the cultivation line up slopes and farther away would follow upon gradual increase of population. It is probable that cultivation reached the head waters of the Wei River at a later time, which would account for the record that the Wei River was clear in former times and later became a muddy stream like the King River.

Possible causes for an increase in the silt content of the water and greater variations in flow are extensive deforestation, cultivation of slopes and overgrazing in the region drained by the river. Evidence of this conclusion is set forth by the senior author in an earlier paper.[40] The watershed of the King is in general included in the region of the loess highlands, of which Cressey says, "Much of the Highlands, except perhaps the desert margins, appears to have once been covered with a continuous forest."[41] Much of this has since been cut down, leaving traces in the higher and more inaccessible mountains and about temples and monasteries where it has been protected.

Sowerby, who traveled over much of this region, says: "In the mountainous regions of Shansi and Kansu, and over the loess hills of Shensi, where uncultivated areas occur, we find such small trees as the Hazel, the Birch, a small variety of Poplar and a stunted Oak growing in great profusion, and forming dense coverts for various kinds of game."[42] Considerable remnants of forest were reported by Licent in the upper part of the King River drainage

HEAD CUTTING OF A GREAT GULLY

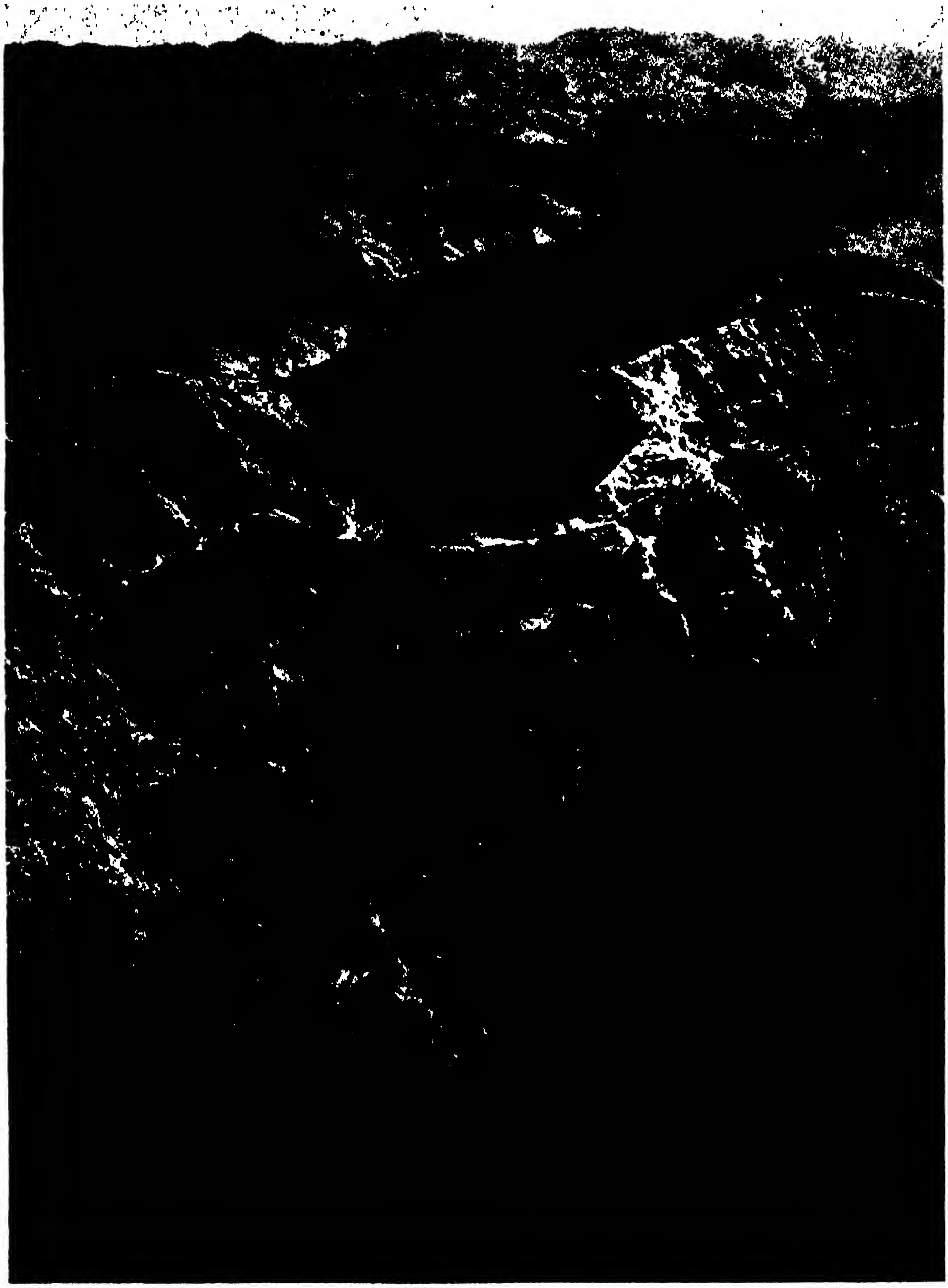
A PART OF THE PACK TRAIN ON THE TRAIL WHICH IS BEING PUSHED UP TOWARD THE DIVIDE. THE HEAD OF THE GULLY SHOWN IN THIS PICTURE SCALES AT LEAST 210 FEET DEEP. SOIL EROSION IN THESE GREAT LOESS DEPOSITS REACHES FANTASTIC PROPORTIONS, BECAUSE OF THE UNIFORMLY FINE TALCUM-LIKE TEXTURE OF THE LOESS. GIVEN LARGE DIFFERENCES IN ELEVATION BETWEEN THE ORIGINAL LAND LEVEL AND STREAM VALLEYS, EROSION TAKES PLACE ON A VAST SCALE AND EXPLAINS THE PRODIGIOUS QUANTITIES OF SILT CARRIED BY STREAMS IN FLOOD FLOWS.

[39] Eliassen and Todd, p. 174; Todd and Eliassen, *Trans. Am. Soc. Civ. Eng.*, 105: 374.

[40] W. C. Lowdermilk, *Am. For. and For. Life*, July, 1925.

[41] Geo. B. Cressey, "China's Geographic Foundations," p. 199, 1934.

[42] A. de C. Sowerby, "Sport and Science on the Sino-Mongolian Frontier," p. 221, 1918.



LOESS-MANTLED HIGHLANDS OF THE YELLOW RIVER

SHOWING HOW THE LANDSCAPE IS CUT UP BY ENORMOUS GULLIES. WHEREVER POSSIBLE, THE LAND IS CULTIVATED TO WHEAT. THESE GULLIES ARE EATING HEADWARD, DESTROYING USEFULNESS OF THE LAND AND ADDING TO THE SILT PROBLEM IN TRIBUTARIES OF THE YELLOW RIVER.

area less than thirty years ago.[43] He also reports deforestation in part of this region.

It is also to be noted that agriculture has been practiced in this region from a remote antiquity. In the "Book of Odes" are references to cultivation of parts of the King drainage area by ancestors of the Chou dynasty,[44] which goes back to 1122 B.C. But such cultivation was at first confined to alluvial valleys.

Some parts of the watershed have been grasslands in historic times. These have been extensively colonized and subjected to grazing by close-cropping animals. The washing away of soil by the summer rains and floods and the deterioration of agricultural lands have been noted in local gazetteers.[45]

As has been pointed out in the case of Mesopotamia and other regions of Asia,[46] wars and internal disturbances are very liable to interfere with the maintenance of irrigation works and to cause their failure. These have probably played their part in the case of Wei valley irrigation system also. Some centuries of weakness and division of the country preceded the building of the new canal by Fu Chien in A.D. 377, during which period this region was repeatedly invaded. Internal disorders also preceded the making of the new canal in A.D. 823. The renewal of irrigation in A.D. 958 followed a period of political weakness and division under the Five Dynasties. The Mongol invasions in the early part of the thirteenth century may be held at least partly responsible for the ruin of the canals and embankments and the desolation of the land reported in A.D. 1240.[47]

Before the building of the latest or modern canal the region had been invaded many times, in 1546 apparently by Manchu Tartars; in 1631 twice by insurgent forces; and so again four years later. The disorders which attended the fall of the Ming Dynasty also affected this region in 1637, when San Yuan was plundered by the forces of Li Tzŭ-ch'eng.[48] Invasions by rebels and banditti continued at intervals, being reported in 1675, 1862, 1865 and 1867.[49]

From the vicissitudes of this remarkable irrigation system in the land of the Sons of Han, where the Han dynasty flourished in the Golden Age of China, it appears that a number of forces must be resolved to maintain such a system in a useful condition through centuries of time. Stream erosion in excavating its channel below intakes of canals was a difficult problem for the ancients to solve. To-day concrete construction makes it possible to establish more permanent base-levels of cutting. The silt burden of the river waters, especially in time of flood from heavy rains, interfered with the usefulness of the project and put it out of commission, and finally disorders brought on by internal troubles or from invasion brought about ruin of the system. Maintenance of an elaborate irrigation system depends also upon orderly government.

Internal disorders within a people may readily occur if they begin to suffer privations of food, as would occur when irrigation waters were lessened or stopped. It is a case of interdependence

[43] Emile Licent, Comptes rendus de dix Annees (1914–1923) de séjour et d'exploration dans le bassin du Fleuve Jaune, du Pai Ho et d'autres tributaires du Golfe du Pei Tcheu Li, 1924, Atlas, map. No. 76; p. 1321.

[44] Legge, "Chinese Classics," Vol. IV, Part II, pp. 437, 484–489; San-shui hsien chih, 1873, 10/4 a.

[45] Ku-yuan chou chih, supplement, 1909. 5/24b, 7/21, 8/42a, b, 9/19a; K'ung-tung shan chih, 1819, Shang/12b; Ch'ien chou chih, 1726, 4/1b; San-shui hsien chih, 1873, 10/8a *ff.*, 10/18 b.

[46] K. A. C. Creswell, *Man*, 15: 68–71, 1915.

[47] Yuan shih 65/11b; Chang-an chih Atlas hsin/15 b.

[48] San-yuan hsien hsin chih (1880) 8/5 a.

[49] San-yuan hsien hsin chih (1880) 8/5b, 6a, 10a, 11a.

HEAD CUTTING OF GULLIES FROM TWO SIDES

CROWDING TRAILS TO THE TOP OF RIDGES. THE PACK TRAIN IS CROSSING A DIVISION HAVING ONLY SEVEN FEET OF THE ORIGINAL LAND SURFACE REMAINING. ON THE RIGHT THE GULLY WALL DROPPED 300 FEET AND ON THE LEFT, 150 FEET, MAKING THE CROSSING OF GAP A THRILLING ADVENTURE.

A GROUP OF CHINESE OFFICIALS AND FOREIGNERS

INTERESTED IN THE CHINESE INTERNATIONAL FAMINE RELIEF COMMISSION STUDYING REJUVENATION OF THE ANCIENT WEI-PEI IRRIGATION PROJECT. CHIEF ENGINEER, MR. LI HSIEH, STANDS ON THE EXTREME RIGHT; THE SENIOR AUTHOR, NEXT ON THE LEFT, AND O. J. TODD, FOURTH FROM THE LEFT IN THE BACK ROW.

between internal disorders and the breakdown of the irrigation works, where it is safe to set up as an objective of government the safeguarding of irrigation projects from damage and impairment by silt.

Summary

The succession of canals built to lead water from the King River for the irrigation of lands in Wei-Pei is an impressive instance of the efforts men have put forth to secure means of livelihood. The difficulties and partial failures encountered may be laid to physiographic changes as well as to failure over a large area to conserve soil and water, through suicidal farming and overgrazing of pasture lands, and the consequences of armed invasions either from outside or inside the country. Finally, after 2,000 years the constructive genius of the Chinese people has made use of modern engineering with power-driven equipment for excavation and construction to restore an age-old irrigation project to a semblance of its first condition. Lands that had lain bare and unproductive are made to yield crops again for its people. But still the high silt content of the irrigation waters remains a serious problem of maintenance. Silt control through erosion control on headwaters remains a necessary condition to the continuing success of this project, as its long history amply implies.

BIRTHS AND DEATHS IN THE UNITED STATES

While the United States set a new record low for infant and maternal death rates in 1940, the "Vital Statistics Summary: United States, 1940," finds that the general mortality rate increased slightly, from 10.6 per thousand to 10.8. This change was due largely to increases in deaths from heart disease, cancer and diabetes. The birth rate, however, also increased from 17.3 per thousand of population in 1939 to 17.9 in 1940, which is the highest recorded from the birth registration area since its completion in 1933. Possibly this indicates a cyclic change closing a long period of a declining birth rate.

This increase in birth rate has been accompanied by a reduction of the infant mortality rate to 47.0 per thousand live births in 1940, which was the lowest ever recorded for the birth registration area. However, the provisional infant death rate for 1941 is 46.2, which would seem to predict a further decline. In 1915 the infant death rate was approximately 100, so that the last twenty-five years has seen a decline of about one half. It is estimated that this amounts to the saving of the lives of 973,626 infants that would otherwise have been among the 3,264,365 infants that died during the past twenty-six years. This reduction in infant mortality has taken place in both the white and Negro races, although the rate for Negroes is still considerably higher than that for the white race. The rate of decline of infant mortality has been slightly greater for the Negroes than for the white race.

The lack of medical care in rural districts, of which so much has been said and written, did not raise the death rate on the farms to the level of the city population. The rural rate in 1940 was 9.8 per thousand of population, while in the cities of more than a hundred thousand residents it was 11.3. The highest rate (12.4) was in cities of between 2,500 and 10,000 population. Males have a decidedly higher death rate than females: 12.0 to 9.5 per thousand of population respectively. There is an even wider difference between the white and other races, the white being 10.4 and "other races" 13.8.

A comparison of the crude death rates for thirty-three specified countries, of which the latest information is for the year 1937, shows that of nations with a dominant white population Chile has the highest death rate. Yet Chile is the only nation on the western continent that has an extensive system of sickness insurance. The only nations that have a lower death rate than the United States are Denmark, Uruguay, Norway, New Zealand, Australia, Canada, Union of South Africa and the Netherlands. Denmark is the only one of these countries that has a nationwide system of compulsory sickness insurance.—*The Journal of the American Medical Association, July 18, 1942.*

SOARING OVER THE OPEN SEA

By ALFRED H. WOODCOCK

WOODS HOLE OCEANOGRAPHIC INSTITUTION

CONVECTION MOTIONS INDICATED BY THE GULLS

FROM October until spring the air over the ocean off the east coast of the United States is, on the average, colder than the water. The heating of this air by the water produces ascending convective motions (motions hereafter referred to as thermals) which are columnar in form during light winds, and which change with higher winds to vertical sheets extending indefinitely up and down (parallel with the) wind. Unlike land thermals, these sea thermals maintain or even increase in strength under night-time or cloudy conditions. Also, as one moves southeastward (say from New York City) under average atmospheric conditions one finds thermals of increasing strength until one gets beyond the Gulf Stream—a condition due simply to the increasing difference between the sea temperature and the air temperature.

These convective motions of air over the sea are revealed by the soaring routines of herring gulls living in this air. The first suggestive feature of their movements lies in the fact that they are not seen far (100 miles or more) at sea until the fall, when cold air from the continent flows out over the warmer sea. The probable reason for this correlation is that the birds are unable to maintain a proper balance between their food supply and the energy requirements for flight until the development of the strong thermals of the fall and winter months make moving about over the sea physically easy.

Below a wind velocity of seven meters per second the birds circle about in columnar thermals, drifting along with the wind as they rise. If the rate of ascent in the thermal is great, the birds will have ample potential energy in the form of altitude to glide back to or beyond their starting point. At wind velocities of from seven to thirteen meters per second, birds soar straight to windward in a fast flight in which they

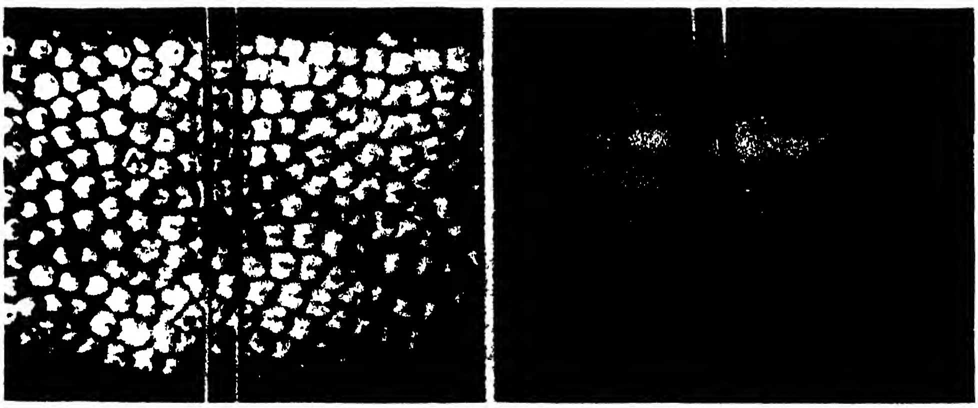


FIG. 1. POLYGONAL CELLS

Left: POLYGONAL CONVECTION CELLS INDICATED BY SMOKE—(SHEAR, 2.3 CM/SEC.) *Right:* LONGITUDINAL (STRIP) CONVECTION CELLS INDICATED BY SMOKE—(SHEAR, 10 CM/SEC.) THE DIRECTION OF FLOW IS FROM LEFT TO RIGHT IN BOTH PICTURES.

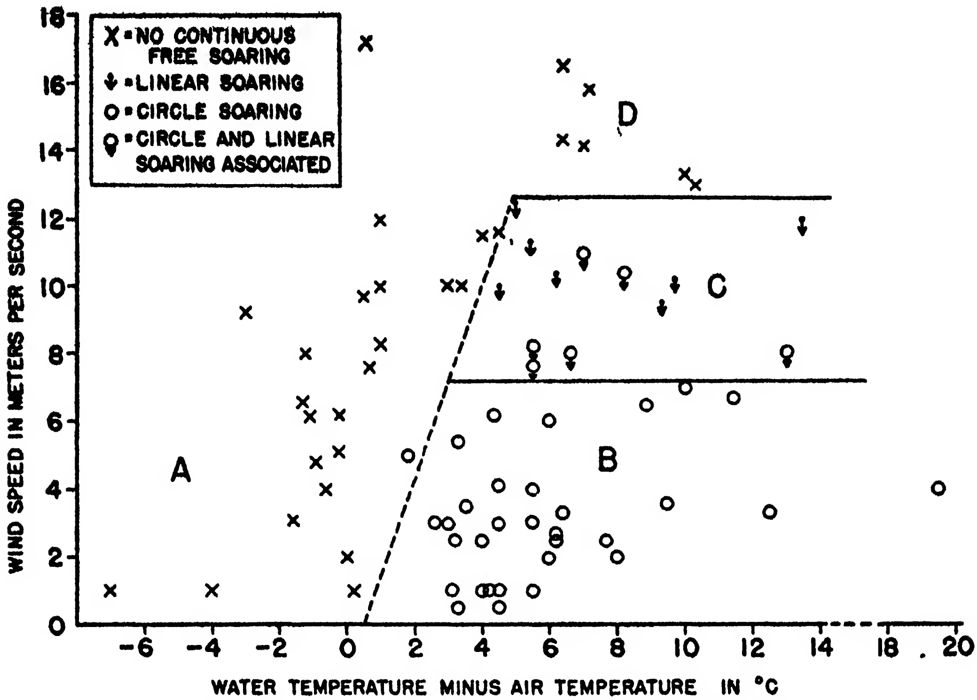


FIG. 2. FLIGHT RESPONSE OF HERRING GULLS
AT DIFFERENT WIND VELOCITIES AND AT VARIOUS RELATIVE AIR AND WATER TEMPERATURES.

gain altitude and over-the-water distance much more rapidly than in the circling flight of lower wind velocities. While moving against a wind of twenty-eight miles per hour, birds have been seen to disappear high to windward in a few minutes time.

Fig. 2 is a graph on which the flight response of the gulls is classified and plotted against the significant physical factors—*i.e.*, the wind velocity and the relative air and water temperatures. Each observation (*i.e.*, each symbol) represents an average period of about six hours during which at any time gulls might have been seen performing the flight routine which the symbol represents. It will be seen that circle soaring is confined to an area between 0.5 meters per second and 7 meters per second wind velocity and where the water is at least two degrees Centigrade warmer than the air. In air moving seven meters per second to thirteen meters per second, and which is more than four degrees Centigrade colder than the sea, the gulls can linear soar directly against the wind. The broken line and the upper solid line mark the approximate upper limits in wind velocity of patterned convective flow for the temperature differences of about plus two degrees Centigrade or more. Above this line (*i.e.*, higher winds) the vertical transfer of thermally unstable air probably takes place through turbulence.

Circle soaring is made possible by thermally unstable air rising from near the sea surface in columns. In light winds these columns are nearly vertical. As the wind increases they become tilted in the downwind direction. This is clearly shown when many birds enter a thermal successively. Not only is the tilt thus indicated, but also the extent of the vertical distribution of the gulls in

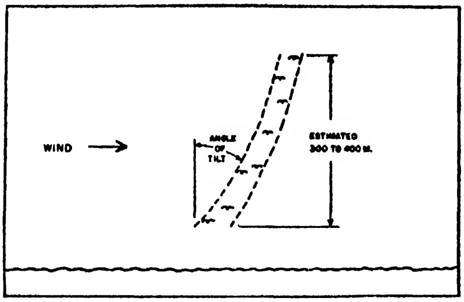


FIG. 3. DIAGRAMMATIC SKETCH SHOWING WHAT IS MEANT IN THE TEXT BY "TILT" AND "THERMAL CONTINUITY."

a thermal shows conclusively that these regions of ascending air have continuity, and are not merely bubbles of rising unstable air (see Fig. 3). Lange[1] (p. 120), speaking of thermals over land, says, ". . . thermals seldom are chimneys of air going up constantly; rather, they are bubbles repeating themselves at intervals." (Apparently sea thermals differ in this respect also.)

Linear soaring is made possible by thermally unstable air rising from near the sea surface in longitudinal strips, which are probably the rising portions of convection cells (diagrammatically idealized in Fig. 4). These strips develop at a wind velocity of between seven and thirteen meters per second, and when the sea is five degrees Centigrade or more warmer than the air. The soaring conditions when these physical relationships obtain give the birds a maximum freedom of movement. With ease they can maintain position or move to windward over the water at wind speeds of eighteen to twenty-eight miles-per-hour.

Both the columnar and strip thermals (as demarked by the gulls) start within 100 to 300 feet of the sea surface and extend up to an unknown height. Soaring altitudes of two thousand feet have been measured with a small range finder. Gulls are seen at much greater heights.

[1] Carl D. Lange, "Soaring Meteorology," Chapter VI of "Flight without Power," 248 pp. New York: Pitman Publishing Corp., 1940.

Elimination of Other Explanations for This Soaring

Anticipating objections that these birds may be using some other known or unknown means of soaring, it should be brought out here that there are three generally accepted (Horton-Smith) requisites for soaring flight. If a bird is soaring, one of three things is happening:

(1) The bird may be descending.

(2) The bird may be utilizing differences of horizontal velocity in the air.

(3) The air in which the bird soars may be rising. It is necessary here to prove that the third condition alone explains the soaring.

In all the circle and linear soaring observations used on Fig. 2 the soaring gulls ascended many hundreds of feet into the air and stayed up for long periods of time. This eliminates condition (1) from further consideration here.

Concerning the second condition, (*i.e.*, horizontal differences of velocity in the air) Rayleigh[2] (p. 465) has said that while using "dynamic soaring" in strata of different relative velocity a bird must, upon entering one stratum, turn around "until his direction is so reversed as to be with the wind of that stratum and contrary to the wind of the other stratum." But, in observations of circle soaring the birds turn both clock-wise and counter-clock-wise in the same area at the same time. Soaring on differences in horizontal velocity depends upon the increase of the wind with height (Idrac) and it is doubtful if this flight is possible far above the surface of the sea (Rayleigh,[2] p. 465). However, circle soaring depends only upon temperature differences between the air and water, and occurs many hundreds of meters above the sea surface. Thus it can be seen that there are several reasons why circle soaring can not be dynamic soaring:

[2] Lord Rayleigh, Rayleigh's Scientific Papers, Vol. 4, pp. 462–479. 1901.

(a) Circle soaring occurs only when the air is colder than the water; while birds can soar dynamically in air that is warmer than the water. (This difference alone is enough to clearly distinguish these two types of soaring.)

(b) Circle-soaring birds can turn in either direction in the same thermal at the same time; while dynamic soaring requires turning in only one direction in the same area at the same time.

(c) Circle soaring occurs at high altitudes; while it is doubtful if dynamic soaring is possible far above the surface of the sea.

In linear soaring the birds do not circle, but move in an apparently straight line. Since dynamic soaring requires a circling flight, then condition (2) (*i.e.*, differences of horizontal velocity) is also eliminated as a possible explanation for linear soaring. Therefore condition (3) only applies to the soaring flight considered in this paper.

Air Motions Used by the Gulls Compared to Experimental Convection Patterns

The sea offers a very steady source of heat, and, with a given wind, the shear between the air and the water is also fairly constant. Experimentally, such conditions are favorable for the development of convective patterns in fluids, with up and down flow occurring at regular intervals. The work of Chandra, Graham[3] and Mal shows the experimental development of various forms of strip and columnar (*i.e.*, polygonal) convection cells in shallow layers of unstable air. Fig. 1, *left*, shows polygonal cells, indicated by smoke in which the motion is down in the center of the cells and up at the cell peripheries. (Sometimes the motion is up in the center and down on the edges.) Fig. 1, *right*, shows the strip cells experimentally indicated by smoke.

[3] A. Graham, *Phil. Trans. Royal Soc. London*, 1934, 232: A, pp. 285–296.

These experimental workers have found that many variations occur both in the direction of flow within these circulations and in the form and size which they assume. These variations are shown to be due to changes in the temperature differences, to changes in the depth of the layer in which the circulation takes place and in the rate of flow within that layer. Brunt[4] (p. 287) suggests that sailplane pilots will eventually be able to tell meteorologists how the convective motions which occur in the air over land compare to those produced experimentally in the laboratory.

The air motions indicated by the gulls over the open ocean are similar to the experimental findings on the following points:

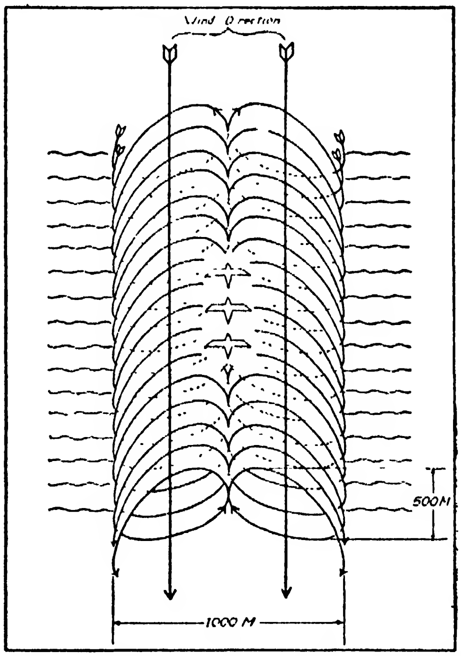


FIG. 4. LONGITUDINAL ROLL CONVECTION CELL

DIAGRAMMATICALLY IDEALIZED, SHOWING APPROXIMATELY THE PROPORTION OF DEPTH TO WIDTH. THE RELATIVE MAGNITUDE OF THE HELICAL MOTION IN THE DIRECTION OF THE WIND IS FORESHORTENED FOR CONVENIENCE IN PRESENTATION.

[4] David Brunt, *Quart. Jour. Roy, Met. Soc.*, Vol. LXIII, No. 271, July, 1937, p. 277–288 (Ref. to p. 287).

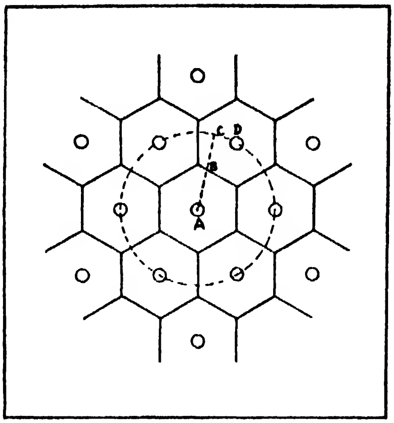


FIG. 5. STEADY STATE
HEXAGONAL CONVECTION CELLS (DIAGRAMMATIC).

(a) No patterned motion is indicated without thermal instability. (See Fig. 2, Section A.)

(b) Columnar circulations are set up in thermally unstable air at low wind velocities. (See Fig. 2, Section B.)

(c) Strip cells (*i.e.*, longitudinal rolls) are set up at moderate wind velocities and greater thermal instability. (See Fig. 2, Section C.)

(d) The convection pattern breaks down with high winds. (See Fig. 2, Section D.)

Discussion of Possible Use of Sea Thermals by Sailplanes

If the circulations which the gulls reveal in the air over the sea are also comparable to the experimental cells in their regularity and type of occurrence, then a sailplane pilot should be able to locate the up-moving air with a fair degree of accuracy, without clouds to guide him. This should be particularly true with the strip cells, for then he could regularly locate lift areas simply by moving cross-wind to the up-moving portion of the next parallel cell (See Fig. 1, *right*). With columnar cells a pilot in one thermal (See A, Fig. 5) might locate another thermal by noting the distance from A to the downdraft region (B), which he could presumably feel. Then, by running an approximately equal distance on the same course to C, and from there following to the right the periphery of a circle whose radius is AC, he should find the up-draft D. If columnar thermals at sea mark the centers of hexagonal convection cells, then any other course the sailplane pilot took from A, with similar subsequent maneuvers, would lead to one of the six up-drafts immediately surrounding the column from which he started. The distance between thermals should be about twice the height of the thermals (Brunt[4]).

The possibility that regular hexagonal convection cells develop in the air over the sea is, of course, questionable. The gulls show, however, that columnar and strip motion exists there, and the similarities listed above (a to f) encourage one to think that the experimental and gull-indicated motions may have other even more useful characteristics in common. Meteorologists such as Brunt[4] and Walker[5] have evidence that cells are sometimes set up over land. The inequalities of contour and heating over land would, however, tend to break up regular cell formations. The sea is much more regular in these respects, and might be expected to be more favorable for the development of convection cells of consistent pattern. The occasional behavior of gulls searching for thermals suggests that there are air motions between the columns which are used to locate the updraft areas. Birds are seen to turn abruptly while in wing-flapping flight and move directly to a thermal, as if they had suddenly encountered an indicator of its existence while still several hundred yards distant. Perhaps peripheral down-draft areas enable these birds to orient themselves in relation to the up-drafts.

Walker[5] (p. 349) speaks of sailplane

[5] G. J. Walker, *Jour. Royal Aero. Soc.*, 37: 657 to 680, 1933; *Nature*, 134: 347–349. 1934.

pilots using "cloud streets," *i.e.*, thermals formed under strato-cumulus roll clouds or "longitudinal cells" which form parallel with the wind over the land. However, he says that these cloud streets are not so useful as the columnar thermals because in them a pilot is restricted to travel in one direction only. For the gulls, however, the longitudinal or strip cells over the sea afford a maximum freedom of movement; the birds being able to move in any direction relative to the water, even in winds of gale force. Brunt[6] (p. 75) speaks of a sailplane flight (Rotter 1936) of 203 miles, which was 138 miles off the straight down-wind line, as a remarkable example of the ability of a sailplane to "travel cross-wind." Gulls riding columnar sea thermals can easily follow the ship moving at right angles to the wind flow (relative to the water), soaring continuously.

Of course, this superior performance on sea thermals may be due to better soaring efficiency in the gulls, though Barringer[7] (p. 176) says, "The best modern sailplanes will outperform most soaring birds." Perhaps it is due to an ability on their part to locate thermals quickly. On the other hand, the difference may lie in the persistency and the regularity of the over-sea thermal as compared to the over-land thermal. Sailplane pilots might soon answer the questions raised.

The first two important questions about sea thermal soaring for the sailplane pilot are: One, will a pilot be able to return to a windward shore after a down-wind flight?; and, two, is the horizontal extent of the sea thermal sufficient for the use of a plane many times the size of a herring gull?

Perhaps a light power plane with a low minimum air speed would be useful to determine something of the size and strength of sea thermals. If not, then a sailplane pilot might start from a leeward shore (say Montauk Point, Long Island or Nantucket Island) in a cool northwest wind and try working to windward with sufficient initial altitude to assure return to port. In this way he could get an idea of the sizes of the thermals and of his ability to work to windward using them. These locations (*i.e.*, Montauk Point and Nantucket) are open to the possible objection that there may be too small an expanse of water to windward to build up an adequate supply of unstable air to form vigorous thermals. However, the gulls seem to have no difficulty at these distances off shore.

Significance of Seas as Source of Heat

If these sea thermals are of sufficient extent and strength for man soaring, they should be much more reliable than land thermals, due to the great source of heat which deep water supplies. The specific heat of water is over three thousand times that of air, so that when a cubic meter of water cools one degree Centigrade, enough heat is released to raise the temperature of over three thousand cubic meters of air one degree Centigrade.

Preliminary figures (Montgomery) on the average rate of heat transfer from the sea to the air by conduction are interesting. When a force three wind (Beaufort scale) is blowing over water which is 6.5 degrees Fahrenheit (average value from U. S. Department of Agriculture Climatic Charts of the Oceans, Chart No. 127) warmer than the air, 7.2 normal calories per square centimeter per day are lost by conduction to the air. Hence, across the water surface under a circular convection cell 1,000 meters in diameter enough heat would be transferred to raise the temperature of 12,420 cubic meters of air one degree Centigrade per second.

[6] David Brunt, *Nature*, 141: 3573, 712–716, April 23, 1938.

[7] L. B. Barringer, "Flight without Power." New York: Pitman Publishing Corp., 1940.

When a force five wind is blowing over water 6.5 degrees Fahrenheit warmer than the air, 12.8 normal calories per square centimeter per day are lost by conduction. This is enough heat to raise the temperature of 23,000 cubic meters of air one degree Centigrade per second for every water surface under a circular cell 1,000 meters in diameter.

These figures give a rough idea of the volumes of unstable air available for vertical circulations in the air over the sea along the east coast of the United States during the winter months under average conditions. Though the heating of the lower air one degree Centigrade will cause only small initial vertical speeds (the acceleration being 3.37 cm per sec. per sec. at 15° C), the great volume of unstable air produced would make possible a continuous thermal difference at considerable altitudes, thus permitting a building up of high vertical speeds (See Lange,[1] pp. 111 and 112). The addition of water vapor to the air being warmed at the sea surface increases the instability of the (already thermally unstable) air. A change in humidity from fifty to one hundred per cent. saturation at ten degrees Centigrade produces a change in the density of the air about equal to that caused by an increase in the temperature of the air of eight tenths of a degree Centigrade.

Concluding Remarks

Cold weather may make flights off the northern states impractical save in the late fall months. However, by moving southwestward along the coast towards Florida, one could find warmer air and at the same time warmer water. Sailplane flights have even been proposed over tropical seas, using a ship as a base for operations. This ship was located at that time in the Atlantic between Cape Verde, Africa, and Cape Sao Roque, South America. Whether these flights were made is not known, but the proposal is mentioned here simply to show that others have thought that sea thermals might prove useful for sailplane flights.

It is hoped that the increasing use of sailplanes by our air forces will soon bring about a testing of the potentialities of convective flow over the seas.

SCIENCE IN WAR AND PEACE

The scientific method in one sense is completely divorced from social consequences. Men of bad will, usurpers of human culture, marauders of our times can with unenviable cunning use the priceless time-tested, experimental method to fashion offensive weapons which can be used to annihilate the environment and the people from whom true science must bring the continuing progress of the world. The metallurgist, who makes possible a fine, keen butcher knife of stainless steel, a useful product of his technology, can do little to prevent the use of that knife for murder by a mad butcher.

In another sense, the utilization of the resources of our planet, including the knowledge and methods and mechanisms produced by science, is a real concern to those who are scientifically creative. It would be logical and not too much to expect that scientists take more than a democratically average interest in preventing destruction and aggression, misappropriation of our material resources, the distribution of good things of this earth among all the peoples, and the assurance of that essential minimum of food, clothing, shelter, education and freedom to all. This means that scientists and engineers must be more than creative specialists; they must be leaders in living and social organization, within the limits of their abilities.

Science can greet with equanimity the unreasoned criticisms that sometimes come to it, charging that science has created new and more deadly weapons. Of course it has. It has created mechanisms and devices for offense, as well as defense, just as it has brought into being all the homely, peaceful things of life, from a comfortable lounging chair to golf tees made of a new plastic.—*Watson Davis in an address before the Institute of Public Affairs, University of Virginia.*

PRESENT STATE OF THE THEORY OF STELLAR EVOLUTION[1]

By Dr. HENRY NORRIS RUSSELL

DIRECTOR OF THE OBSERVATORY AND RESEARCH PROFESSOR OF ASTRONOMY, PRINCETON UNIVERSITY

HERSCHEL, almost a century ago, compared the student of the stars with a traveler visiting a forest. An alert observer might see there seeds falling to the ground, others sprouting, little saplings, sturdy young trees, monarchs of the forest, hollow, battered trunks and fallen boles mouldering into earth; and so, in one ofternoon, attain all the data required to interpret the life-cycle of a tree.

The analogy is very tempting, but it fails at one vital point. We unconsciously assume that our traveler had a general knowledge of the processes of life. Otherwise he might conclude that oaks grew into acorns or that every blade of grass would in time become a tree.

Even with such knowledge, he would be at a loss unless he had visited a long-established forest, older than any tree in it. In a plantation of trees set out at the same time, or even in second- or third-growth woods that had grown undisturbed since fire or the axe had cleared the land, he would miss out important stages of life-history and might reach strange conclusions.

At the beginning of the present century, not enough was known about individual stars to justify any generalizations. Since then a great mass of information has been accumulated concerning distances, luminosities, surface-temperatures, diameters, masses and densities, providing abundant material for testing the predictions of theory. But the empirical methods of natural history proved inadequate to suggest a good theory.

For example, we know that hot bodies tend to cool down; hence it was once supposed that white stars (hot on the surface) were in early stages of evolution, and gradually changed into red, cooler stars. The terms "early" and "late" applied to the corresponding spectral types persist almost to this day, as a sort of literary fossils bearing the mold of this extinct theory.

The problem of stellar evolution is not one of natural history, but of physics. Any reasonable theory must be a by-product of a physically sound theory of stellar constitution, which shows how the observable characteristics of a star-mass, radius, luminosity, etc.—are related to its composition and its internal structure. The central problem is this: Given a large quantity of matter of known mass and atomic composition, isolated in space; to find its configurations of equilibrium, and its steady states of slow secular change. The sequence of these changes defines the evolution of the stars.

The problem may be simplified by limiting the primary study to non-rotating bodies—leaving the complications resulting from rotation for later study (which is as yet scarcely begun). A second, and still greater, simplification arises from the fact that all observable stars are very hot, even at the surface. The properties of matter within them are thus greatly simplified, and general considerations of atomic physics suffice for their discussion.

The knowledge of atomic structure, especially that derived from ordinary and x-ray spectroscopy, is the foundation upon which theoretical astrophysics rests. We can now predict with assur-

[1] Based on an address presented at the Inter-American Congress on Astrophysics, Puebla, Mexico, February 19, 1942.

ance the behavior of atoms even under the most extreme conditions of temperature and pressure which prevail within the stars. It is certain that the temperatures through most of the interior of a star are to be measured in millions of degrees, and that, despite the enormous pressures, the atoms are heavily ionized, or stripped of their outer electrons, reducing the lighter ones to bare nuclei. Two of the three relations which determine the constitution of the stars are now known with adequate accuracy—the *equation of state,* connecting temperature, pressure and density, and the *equation of energy transfer* between hotter and cooler regions. Both involve the state of ionization of the gas and the pressure of radiation, and both are complicated; but the calculations, especially for the opacity, have been greatly facilitated by the preparation of tables.

The third relation, the *equation of energy-liberation* from latent sources, depends normally on nuclear reactions, which are rapidly being investigated as nuclear physics advances. The transitions, so far known, are of the non-equilibrium type, in which previously existing stores of energy are liberated, by one-way processes. Reversible reactions, at equilibrium rates, are possible, but would be sensible only at temperatures very much higher than are to be anticipated in the stars. Under certain conditions, the release of gravitational energy by contraction of stars appears to be important.

The mechanical equilibrium of a star can be studied with the aid of the equation of state alone. For any "model" of given composition (in which the density is given, as a function of the central distance, subject to certain normalizing factors), the temperature required for equilibrium may be uniquely determined. If the equation of heat-transfer is added, the flux of heat through the mass can be found.

If these calculations indicate that more heat flows out through the outer surface of a thin spherical shell than flows into it through its inner surface, it must be assumed that the difference represents heat generated in some way within the shell. This is not disturbing; but calculations which show that less heat flows out of the shell than flows into it demand the existence within it of "sinks" of heat, in which it is transformed into latent energy of some other sort. According to our present knowledge, the long-continued existence of such a situation at stellar temperatures and pressures appears extremely improbable, and models which lead to it are discarded.

A great variety of possibilities remain. Two of these models deserve special mention:

(1) Eddington found, many years ago, that if the product of the rate of liberation of heat by the opacity is assumed to be constant, the mathematical analysis is very greatly simplified and leads to a definite model, with the central density 54 times the mean density. Results calculated from this simple model agree surprisingly well—though not perfectly—with such observational tests as can be made, and it is now widely called the "standard" model, though the physical assumptions upon which it is founded are known to be inexact.

(2) A physically much more acceptable model is the "point-convective." This has an outer region in which no heat is generated, and the heat-flow takes place by radiation through the hazy gas, and a small inner core in which all the heat is liberated, and the flow is so rapid that it has to be carried by ascending currents of hotter, and descending currents of cooler gas. The calculation of such a model demands laborious numerical integrations. Results have been obtained for the Sun (that is, for a body of the same size, mass and brightness)

and for Sirius. They lead to models fairly similar to Eddington's, but with higher central densities (64 times the mean density for Sirius, and 78 for the Sun).

When once we have an acceptable model, we may use it (as Eddington was the first to realize) to attack the apparently impossible problem of the chemical composition of the main interior mass of a star. We can find that of the star's atmosphere—the very outermost portion—of course, from the spectrum, but the interior is hidden under a hundred thousand miles of incandescent and effectively opaque material and might be supposed to be as inaccessible as anything in the universe.

However, if we are given the model on which a star is built, its mass, and its radius, the amount of heat which will leak out to its surface, and hence the star's brightness, can be calculated, provided that we know the atomic composition of the material. This influences the result mainly by changing the average "molecular weight" of the gas—taking this average for all the particles—free electrons and wholly or partly stripped atomic nuclei. When the stripping is complete, as it is approximately inside the stars, this gives a mean value of 0.5 for hydrogen, 1.3 for helium and nearly 2 for all other atoms.

The composition with which we have to deal depends therefore upon the relative abundances of hydrogen, helium and all the "heavy atoms" together. The larger the percentage of heavy atoms, the hotter the star will be inside, the more heat will escape to the surface, and the more brightly it will shine. When, however, the percentage of heavy atoms is very small, the gas becomes less opaque, heat escapes more easily, and a star of practically pure hydrogen or helium would be bright.

For the same composition, the luminosity increases rapidly with the mass, and decreases slowly with increasing radius. Change of model has usually a rather small influence. Strömgren, working with the easily calculated standard model, has thus shown that a body of the size and mass of the Sun, and containing hydrogen, heavy atoms, but no helium, would shine with the Sun's brightness if it contained 65 per cent. by weight of heavy atoms, and 35 per cent. of hydrogen, and also for 0.2 per cent. heavy atoms and 99.8 per cent. hydrogen—corresponding to the two situations described above. A series of solutions connecting these two exists, with hydrogen and heavy atoms ranging between the given limits and helium rising to 42 per cent. and returning to 0.

This, by itself, would leave us in great uncertainty. But we have said nothing yet about the process by which heat is liberated inside the stars.

Energy-liberation in main-sequence stars (including the Sun) has been fully accounted for by the already classical discovery of Bethe—the catalytic process by which carbon and nitrogen transform hydrogen into helium without being themselves consumed. Of the six reactions

$$C^{12} + H = N^{13} + \gamma \qquad N^{13} = C^{13} + \varepsilon^{+}$$
$$C^{13} + H = N^{14} + \gamma$$
$$N^{14} + H = O^{15} + \gamma \qquad O^{15} = N^{15} + \varepsilon^{+}$$
$$N^{15} + H = C^{12} + He^{4}$$

all have been observed in the laboratory, and it is now certain that under the conditions prevailing in main-sequence stars they would liberate energy at a rate of the right order of magnitude. The final particle reaction, which produces carbon, is of the order of a million times more probable than the radiative process producing O^{16}, so that the cycle is almost perfectly regenerative.

The point-convective model for the Sun gives a hydrogen content of 35 per cent. (if there is no helium) and a central temperature of 25.7×10^{6} degrees. The observed energy-production of the

Sun would be met by Bethe's cycle if the combined abundance of carbon and nitrogen was 0.0067 per cent. by weight. More plausible values are obtained by assuming the presence of helium, which, according to Strömgren, increases the hydrogen, diminishes the mean molecular weight and the internal temperature. As the rate of nuclear reactions varies as T^{17}, a larger quantity of carbon is then required.

The possible values for the Sun's composition (by weight) then come out:

Hydrogen	0.61	0.51	0.43	0.36	0.35
Helium	0.35	0.42	0.43	0.29	0.00
Heavy atoms	0.04	0.07	0.14	0.35	0.65
Carbon and Nitrogen	0.025	0.0063	0.0017	0.00026	0.000067
Ratio	0.62	0.09	0.012	0.0008	0.0001

The ratio of C + N to all heavy atoms is given in the last line.

It now appears that the Sun's interior can not contain much more than 61 per cent. of hydrogen, for in that case, even if all the heavy atoms were carbon and nitrogen, they would not suffice to run Bethe's cycle fast enough to keep the Sun shining as it does. If we had any independent way of estimating what proportion carbon and nitrogen formed of all the heavy atoms, we could find the composition of the Sun. The best information we have is an investigation by Unsöld upon the spectrum of the hot star Tau Scorpii, in which he finds that they form 16 per cent. by weight of all the heavy atoms. Taking this as a general guide, we may conclude that the second column of our table is probably much nearer to representing the Sun's composition than those on each side of it, while the last two columns are very improbable. It thus appears that the Sun now contains nearly as much helium as hydrogen. It is kept going by "burning" hydrogen into helium.

Hence we may be fairly sure that the Sun is not yet half way through its possible evolutionary course (as measured by this transformation). If it started with very little helium, it is now well on to half-way through; but if it started with a good deal of helium, it is in an earlier stage. Unless we can find out how much helium it had when it started shining, we can deduce no more by this argument.

We can work out, however, what the Sun was like in earlier stages of its history, and will be like later. As it turns its hydrogen into helium, the mean molecular weight of its material would increase and the internal temperature rise. This would cause a rapid increase in the supply of heat from Bethe's process, which varies roughly as the 17th power of the temperature. The rate of escape of heat from the interior to the surface, and into space from this, would also rise; but, to get the two to balance, the Sun would slowly have to expand, becoming a little larger, and much brighter and hotter. At last, when only a few per cent. of the hydrogen was left, it would cease to expand; but it would continue to grow brighter and hotter till the hydrogen was practically exhausted. Then it would draw on its gravitational energy, contract rapidly and end as a dense white dwarf star.

Table 1 shows these changes in diameter and luminosity, and the corresponding values of the spectrum and

TABLE 1
EVOLUTION OF THE SUN

Hydrogen Percentage	Molecular Weight	Radius	Luminosity	Spectrum	Abs. Mag.	Time Interval	Number of Stars
91	0.536	0.875	0.12	dK8	8.2	(3.9)	(0.04)
81	0.574	0.900	0.19	dK5	7.1	5.4	0.16
71	0.618	0.921	0.31	dK3	6.2	3.3	0.33
61	0.670	0.964	0.54	dG8	5.4	1.9	0.62
51	*0.731*	*1.000*	*1.00*	*dG2*	4.7	1.0	1.01
41	0.803	1.040	1.95	F4	3.9	0.52	1.55
31	0.894	1.076	4.08	A8	3.2	0.25	2.19
21	1.005	1.132	9.22	A3	2.6	0.11	2.74
11	1.149	1.184	23.5	B9	2.1	0.04	2.93
6	1.238	1.193	40.4	B7	1.8		
1	1.341	1.129	77.2	B5	1.5	(0.013)	(1.38)

absolute visual magnitude (which astronomers commonly use in describing the stars). The fifth line, representing the Sun as it now is, is printed in heavy type.

Upon comparing these calculated properties of pre-solar and post-solar stages with the known average values for stars of the various spectral classes, and belonging to the main sequence, it appears that the pre-solar stages would be hardly distinguishable in brightness from the general run of reddish dwarf stars. They would be considerably more massive than the average, but this could be detected only if, by good luck, they belonged to binary systems.

The calculated post-solar stages, however, are very much fainter, as well as less massive, than average stars of the same spectral types.

The distances and luminosities of some thousands of the brighter stars have now been measured, and not a single object of this sort revealed by reliable observations. Here we have a new fact, evidently bearing upon stellar evolution. What is its significance? It is usually said in explanation that the pre-solar stages are faint, and spend their energy slowly, while the post-solar are bright spendthrifts; so that the latter live their lives so quickly that, at a given instant, few of them can be found.

It is easy to calculate the relative times which our hypothetical Sun would spend in each of the intervals centering on a line of the table, and these are given in the next to the last column. The first entry, in brackets, represents the change from 91 to 86 per cent. hydrogen, the next 86 to 76, and so on, except for the last, which is for 6 to 1 per cent. Adding them up, it is found that the pre-solar stages of evolution should take longer than the post-solar, in the ratio of 15.1 to 1.3.

This looks favorable to the argument; but an important factor in the problem has been forgotten. Our conclusion so far is true for any particular star. But we astronomers make our lists of stars for observation by their apparent brightness. If we go down, as we practically always do, to a given limit of apparent magnitude, we get the stars of great real brightness up to a large distance, but record only those stars of small luminosity which are near us. This well-known observational selection gives a great advantage to the bright post-solar stages. When allowance is made for it, we get the numbers in the last column of the table—and now find the post-solar stages favored in the ratio of 11.4 to 1.3.

The number of stars in the solar stage itself (line 5 of the table) is 1.01. For every star brighter than (say) the 5th magnitude and in the solar stage, we should find more than ten in the post-solar stages. We actually find twenty in the solar stage, and none in the other.

Something is wrong. The calculations have been carefully checked, the physical theory is well founded. How about our assumptions? One—that the stars are strewn nearly uniformly in space up to the distance we have to consider—is known to be very nearly true. But we have tacitly made another—that the stars we are dealing with started their careers indiscriminately at all sorts of times. This is necessary in order that the numbers of stars in the various stages (unaffected by observational selection) shall be proportional to the durations of these stages.

We had no proof of this at the start; its consequences disagree violently with the observations. Hence it must be false.

Every thing makes sense if we assume that the life of the visible universe, since stars like the Sun began shining, has not been long enough for them to reach the bright post-solar stages. This conclusion has been reached by an argument, altogether independent of any measurement, or even estimate, of time-intervals in years.

Now the amount of energy liberated

by the transformation of 1 per cent. of the Sun's mass from hydrogen into helium is known, and would keep it shining at the present rate for just about one billion years. Hence the unit in which the time-intervals in Table 1 is measured is ten billion years. The longest estimate of the past history of the stellar universe—since things went on as they are doing now—is about six billion years (from Paneth's recent work on meteorites). Most methods indicate half as long or less.

The conclusion that stars like the Sun have had time for very little evolutionary change since the origin of the Galaxy is therefore not new—though the reasoning here presented affords an independent proof of it.

Stars less massive than the Sun are so much fainter that the time-scale of their evolution must be much slower. We see them now substantially as they have "always" been. The very luminous stars at the top of the main sequence present a very different problem. Each component of the eclipsing variable Y Cygni, for example, has 17 times the Sun's mass, and—as best we can estimate—30,000 times its luminosity. The transformation of its whole mass from hydrogen to helium would keep it shining at the present rate for only about 60 million years. Hence, such stars either have access to some still more gigantic source of energy (such as the hypothetical complete annihilation of atoms) or they started shining only recently on the galactic time-scale. The former suggestion finds no support—and many difficulties—in our present knowledge of nuclear physics. The latter, which till very recently was hard to understand, finds support in researches in progress by Whipple of Harvard and Spitzer of Yale. It is conclusively proved by absorption phenomena that scattered particles of dust and atoms and molecules of gas are widely distributed in interstellar space. Both these investigators have shown independently, and by somewhat different methods, that such particles may tend slowly to concentrate toward the equatorial plane of a rotating galaxy. Whether they can assemble in sufficiently great amounts to concentrate at last into massive stars is not yet fully investigated, but enough has already been done to make this line of approach appear hopeful.

TEMPERATURE CONTRASTS IN THE UNITED STATES

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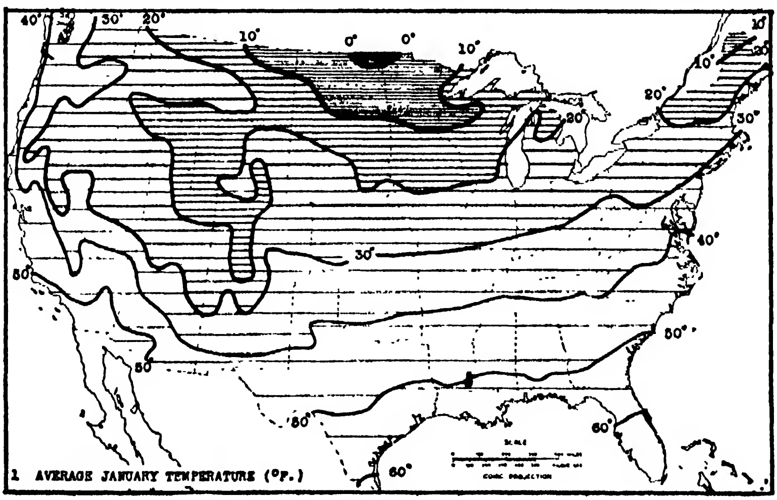
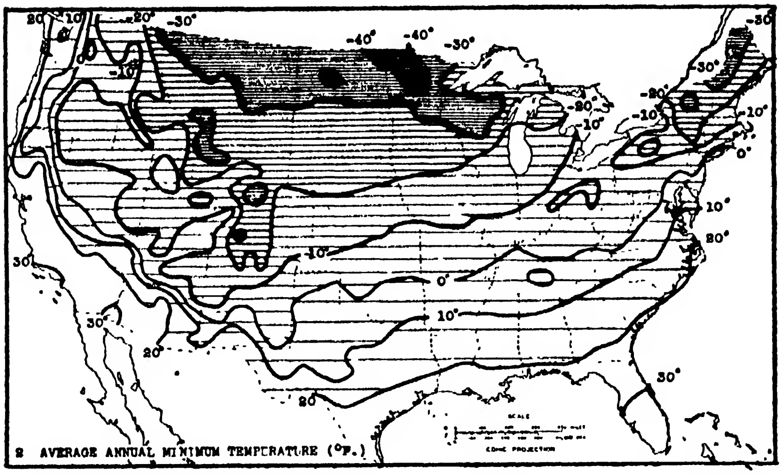
WIDE contrasts with respect to several significant temperature conditions in the United States are shown by the accompanying maps. They are based on the data for 40 years, 1899–1938, and most of them use records from about 5,000 stations. They therefore have a considerably firmer basis than had corresponding earlier maps, for example, those in the Atlas of American Agriculture (1928), most of which were based on data for 20 years for 200 to 600 stations. These maps are redrawn, shaded, and somewhat simplified, from maps in the 1941 Yearbook of Agriculture, "Climate and Man." The accompanying discussion is original.

Map 1 shows that the average January temperature ranges from about 60° F. in central Florida and southern Texas to below zero at the Canadian border near the center of the continent. The tempering influence of the winds off the Pacific Ocean is conspicuously shown—the northwestern corner of the country averages no colder in January than northern Texas or northern South Carolina. The Great Lakes also raise average winter temperatures appreciably. The Atlantic Ocean causes, however, only a slight rise in average temperatures near the coast, except in New England, because in January the average wind is from the west, not off the Atlantic. The depressing influence of the higher altitudes in the Rocky Mountains is evident, but the Appalachians cause only slight flexures of these isotherms.

Map 2, of the average annual minimum temperatures, shows a progressive northwestward decrease from central Florida, where a temperature slightly below freezing occurs at least once during each normal winter. Normally, the part of the country which is coldest in winter is an area west of Lake Superior, where −40° occurs at least once each winter. The tempering influence of winds off the Pacific Ocean is conspicuous on this map; at the western end of



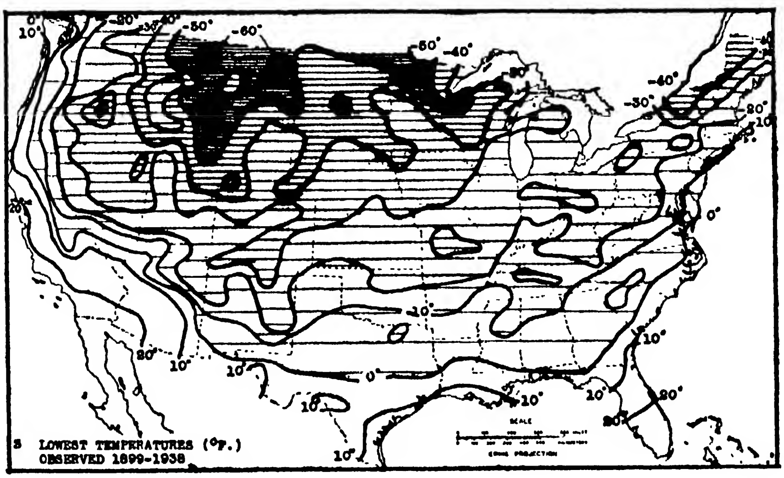
1 AVERAGE JANUARY TEMPERATURE (°F.)



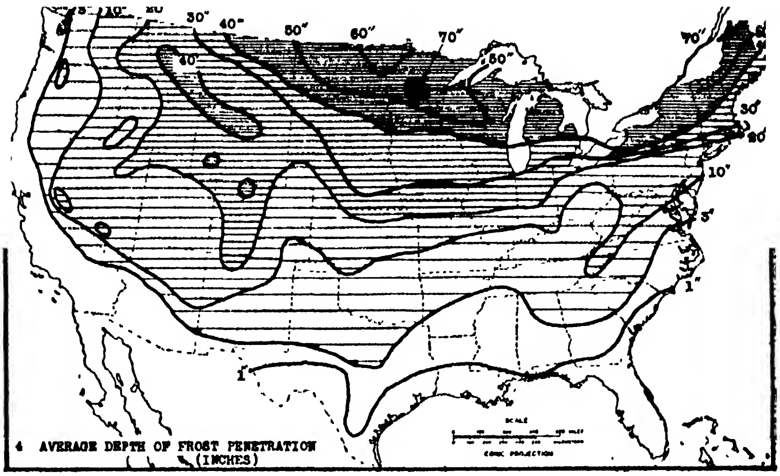
2 AVERAGE ANNUAL MINIMUM TEMPERATURE (°F.)

the Canadian border the coldest temperature normally experienced is 60° higher than that recorded 1,200 miles to the east, and is no lower than that of northwestern Florida. The Great Lakes also interfere strongly with low temperatures; for example, the area just east of Lake Huron normally experiences in its coldest spell only – 10°, while most of New England and Iowa experiences from – 20° to – 30°. The Atlantic has a greater influence upon minimum than on average January temperatures, apparently because of the large amount of fog and other condensation in exceptionally cold weather close to the coast. Low temperatures extend farthest south in the Rocky Mountain region, where the winters are dry and where the altitude is considerable. Note that – 30° occurs each normal winter in Colorado, – 20° in New Mexico and 0° in western Texas and northern Arkansas. The higher minima in the Pacific States reflects the greater amount of latent heat of condensation as well as the tempering influence of winds off the Pacific, for the winters are wet on the Coast.

Map 3 shows that during the 40 years studied, 0° has been recorded at least once close to the Gulf of Mexico in northern Florida, and – 60° in parts of



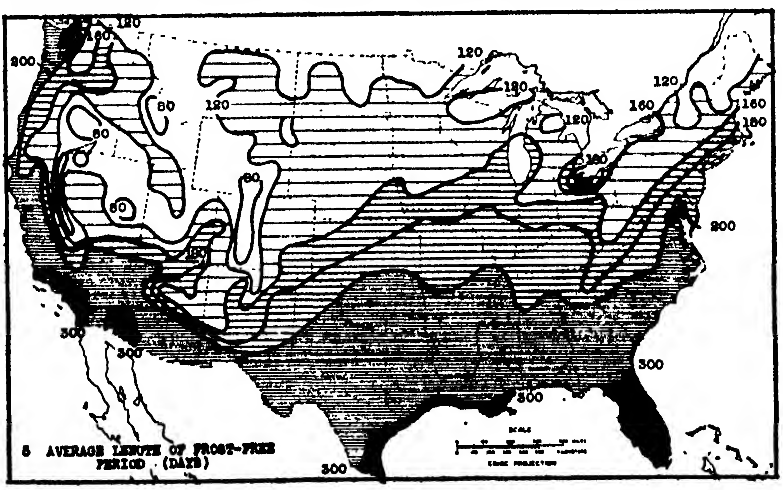
3 LOWEST TEMPERATURES (°F.) OBSERVED 1899-1938



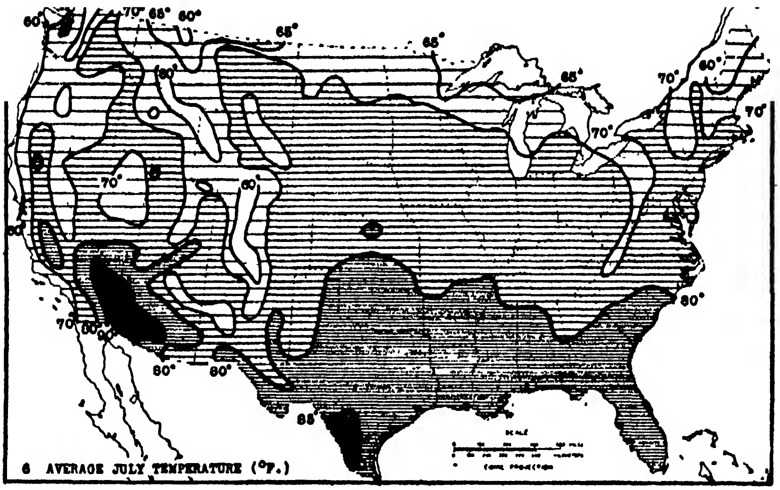
4 AVERAGE DEPTH OF FROST PENETRATION (INCHES)

Montana and northwestern Wyoming. The much more extensive area of at least −30° in the western than in the eastern half of the country reflects the influence of greater elevation there and of less atmospheric moisture. Although in the West temperatures of −30° and colder have been experienced farther south than in the East, this map shows that 0° and −10° extended about as far south in Florida and Mississippi as in Texas. This reflects the fact that exceptional cold waves are associated with great atmospheric highs which move southeastward from Montana. The tempering influence of the Atlantic coastal atmospheric conditions is shown conspicuously on this map. Several coastal stations at their coldest minute in 40 years were about 20° less cold than areas only 200 miles inland, despite a northwesterly wind blowing toward the Coast.

Map 4 shows that the average depth of frost penetration is more than 50 inches in a sizable area east of the Great Plains, but is less than 3 inches along the western and southern coasts. The deep penetration of frost in the Northeast, despite the normal presence of winter snow, shows that prolonged, severe cold penetrates a snow-cover. Indeed, a snow-cover is often conducive



5 AVERAGE LENGTH OF FROST-FREE PERIOD (DAYS)

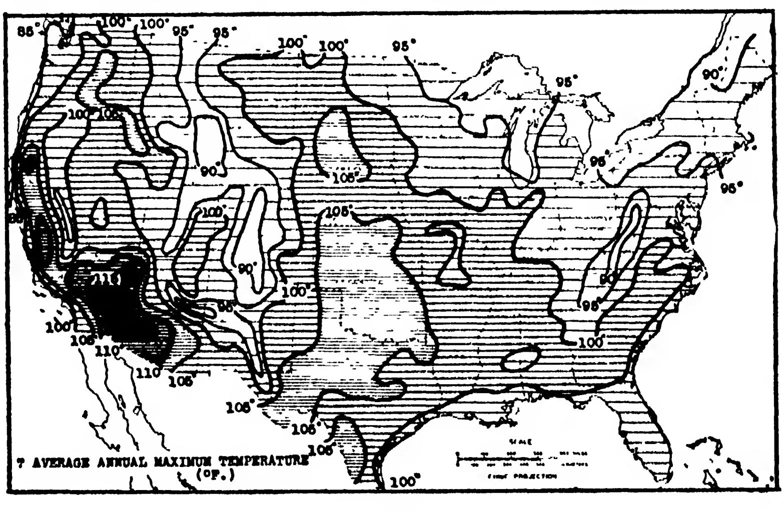


6 AVERAGE JULY TEMPERATURE (°F.)

to exceptionally low atmospheric temperatures, by reducing solar heating and accelerating loss of heat at night.

The average length of the frost-free period (Map 5) varies from about 300 days at the south to less than 120 days along most of the northern border and in the mountains. The influence of winds off the Pacific and the Great Lakes is clearly shown on this map, and the effect of the Atlantic Ocean is more evident than in other maps of this series. The great influence of the thin air of high altitudes is shown by the presence of sizable western areas where the frost-free season is less than 80 days. Much of the northern Appalachians also is relatively cool, even being too cool for corn.

The average July temperature (Map 6) shows far less latitudinal contrast than is true for January, most of the country having a July average within a few degrees of 75°. Only small areas, except in the mountains and on the immediate Pacific Coast, have average July temperatures that are not above the optimum for mankind (about 65°, according to the evidence presented by Ellsworth Huntington and other inves-

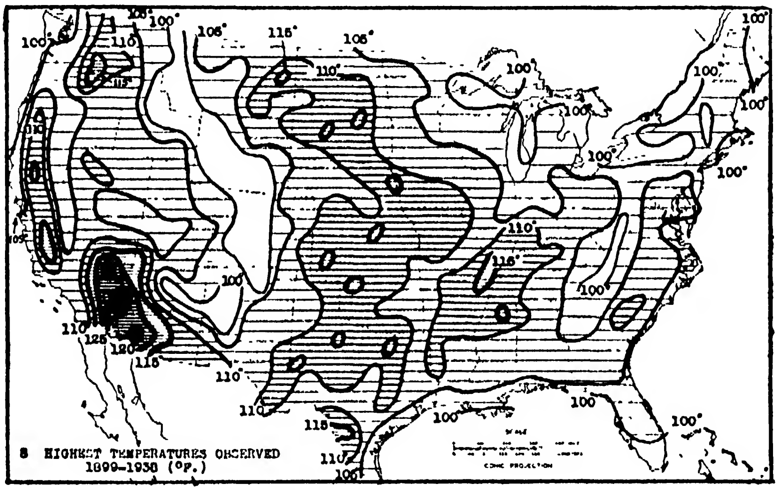


7 AVERAGE ANNUAL MAXIMUM TEMPERATURE (°F.)

tigators of the subject). The influence of the Appalachians is exceptionally evident on this map; western North Carolina has as low an average July temperature as much of northern Montana.

The highest temperatures experienced during the normal summer is the subject of Map 7. It shows that 100° or more occurs in most of the country each normal summer (generally late in July). The chief exceptions to this generalization are the Northeast, the west coast (especially north of San Francisco) and locally less than 100°. Southern Florida in the hottest weather is less hot than western Maine or North Dakota for three chief reasons: it has more cloudiness; the longest days are distinctly shorter; and sea breezes from the nearby ocean temper the heat. This map, the most irregular of the series, reflects local influences of sunshine as compared with cloudiness on record-making hot days. Other influences causing irregularity are water bodies, the dryness and color of the soil, and local differences in altitude.

A map, not published here, of average



8 HIGHEST TEMPERATURES OBSERVED 1899–1930 (°F.)

the mountains and, strange to say, Florida. A temperature of 105° occurs each normal summer in sizable areas as far north as South Dakota and central Washington. Temperatures of 115° are normal on the hottest day of the summer in a part of the arid Southwest.

During the 40 years studied, the highest shade temperatures officially recorded have exceeded 100° in all but a few areas left unshaded on Map 8. The largest of these is in the western mountains. The latitudinal influence is different than might be expected. Near the Canadian border, several places have had maxima of over 115° (but less than 120°), while along the Gulf of Mexico the highest temperature recorded was

July wet-bulb temperatures shows a considerably greater latitudinal contrast than is shown by Maps 6, 7 or 8. The Gulf Coast, Florida and the coast of South Carolina have July wet-bulb temperatures averaging 75°, while much of the North and nearly all the West have averages below 65°; most of the Rocky Mountain plateau region has averages of less than 55°, as does the northern part of the Pacific Coast. Thus, although most of Florida seldom has a temperature as high as 100°, while South Dakota gets 105° each normal summer, Florida has a wet-bulb temperature averaging between 75° and 80° in July, while South Dakota's and Maine's averages are between 60° and 65°.

Hence, because of its humidity, Florida (except on the very seashore) feels much hotter than does South Dakota or Maine.

In brief, there are pronounced regional contrasts in temperature in the United States, which differences help to make the regional diversity which enables the United States to produce a great variety of crops, and to have within its own borders temperature conditions suitable for many other human activities, including recreation. Seven major influences producing the contrasts are: (1) latitude, through its influence on the angle at which the sun's rays penetrate the atmosphere and strike the surface, and hence in their effectiveness; (2) length of day and night; (3) altitude; (4) the ocean, with its almost uniform temperatures; (5) inland water bodies, especially the Great Lakes; (6) atmospheric humidity and soil moisture; (7) normal wind directions, including the course usually followed by atmospheric highs.

Latitudinal contrasts are evident in parts of all the maps, but are most conspicuous on the one of average January temperatures. Then, however, the influence of the angle of the sun is supplemented by the sharp northward decrease in the length of day. Latitudinal contrasts are least in July, when the longer days in the North largely counteract the influence of less effective insolation per hour. The influence of altitude is most evident during times of cooling, especially at night; the thinner air of higher altitudes enables a more rapid escape of heat. (During the day, however, thin air often permits a rapid surface heating.) The effects of altitude contrasts are therefore most clearly shown in the maps of minimum temperatures, especially of the duration of the frost-free season. The influence of the ocean is much more evident on the west coast than on the east because most of the United States has westerly winds (NW, W, SW) much of the time. The chief exception is the southern part of the country, which often has winds from the southeast or south in summer. Winds from the Pacific keep the adjacent coastal regions cool in summer and mild in winter. Winds from the Gulf and Atlantic help prevent nearby temperatures from rising to great heights in summer. The Great Lakes have a conspicuous influence upon minimum winter temperatures and upon the length of the growing season, because they remain unfrozen and yield much heat when the air is colder than they are. Their depressing influence on high temperatures is also evident. Low atmospheric humidity facilitates heating and cooling, while moist air greatly interferes in three chief ways: moist air is more often cloudy; the formation of dew, fog and frost sharply checks cooling, and their subsequent evaporation retards heating; moist air often yields rain, which means wet ground, usually relatively dense vegetation and occasional bodies of surface water. These latter retard heating and cooling. The influence of local contrasts in moisture conditions upon temperature are evident on all these maps, but are most conspicuous on those of the length of the growing season and of maximum and minimum temperatures. The significance of the direction of the prevailing winds is conspicuous with respect to the ocean, as already mentioned. The influence of the normal direction of movement of the atmospheric highs (from northwest to southeast into the South) is most evident on the map of exceptionally low temperatures.

THE FIRST ARTIFICIAL RUBBER TIRE

By Dr. ALBIN H. WARTH

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THE following story is a true account of the public exhibition of the first artificial rubber tire ever seen in the United States. This artificial rubber tire represented the glorious achievement of a goal for which some of the greatest chemists in the world had striven for a century. It was in 1912 at the time of the Eighth International Congress of Applied Chemistry, which was held in New York City.

On Monday, September 9, 1912, there was rolled into the large lecture hall or amphitheater of the then new College of the City of New York a large rubber tire under cover, for it was held by the lecturer as a surprise package to be sprung on the audience of distinguished scientists from all parts of the world at the close of the lecture. The fundamental research in the chemistry of rubber and the making of artificial rubber belonged first to England, and then to France, Germany and Russia in succession, but the finishing touches to this research accompanied by laborious laboratory work of a team of fifteen chemists belonged to an industrial concern in Elberfeld, Germany, which was managed by a Carl Duisberg, the lecturer.

Duisberg lectured on the latest achievements and problems of the chemical industry as he saw them. He had with him the richest collection of diagrams, products and materials of all kinds that I had ever seen. They completely covered the long laboratory desk on the speaker's platform. Some of these things, particularly in the alloy steels, really heralded World War I, which was actually to follow two years later. But that is aside from the subject at hand. Duisberg, a short stocky man with a ruddy complexion, illustrated his paper by exhibits and lantern slides, to an audience that was delightfully enthusiastic to find so much that was new to them.

It is interesting to look back to the broad scope of chemical development on the Continent at that time, as it was outlined by the lecturer, who in well-spoken English said: "I invite you to make a flight with me in an airship, as it were, over the fields where the chemical industry holds sway and, from our point of vantage, to take a bird's-eye view of the latest achievements of the industry. Now and then, we shall make a landing and examine the most attractive features a little more closely." Then he proceeded with outlining one achievement after the other—the production of power; the production of by-products; the production of cold; the production of giant chemical equipment; quartz vessels; refined steel; nickel steel, chromium, tungsten and molybdenum steels, electro steel; electrolytic iron; sulfuric acid; ammonium sulfate; nitrogen compounds from the air; soda and chlorine; electrolytical detinning (patent process of Thomas Goldschmidt of Essen); peroxide of hydrogen; rare metals, artificial precious stones; coal tar preparations; synthetic colors, synthetic perfumes; artificial silk (viscose); acetyl cellulose; non-inflammable cellulose (cellox); and finally rubber—synthetic rubber.

We all felt a bit amazed at the outstanding progress that was being made and its important bearing on civilization. These commercialized developments should have spelt peace, but with

a few exceptions they signalled the coming of war. The airship had completed its survey of the fields and it was ready in the form of the Graf Zeppelin to challenge. Is it any wonder that Duisberg said in the spirit of Faust, "Who brings much will bring something to many." Duisberg closed his lecture with some words he quoted from Schiller in German, "Only the serious mind, undaunted by obstacles, can hear the hidden spring of Truth."

At the moment Duisberg lifted the artificial tire high in the air, bounced and rolled it, and the audience went wild with applause. So startling was this performance that many another scientist was politely incredulous. A few snickered and said, "I don't believe him—you can't tell me that tire is made of artificial rubber," or similar words to the same effect.

Professor Leon Lindet, of Paris, rose to his feet, and moved a vote of thanks, "Mais vous applaudirez aussi cette admirable cohort de chemistes—" The motion was seconded by an outstanding American chemist, the late Dr. Arthur D. Little of Boston. Little said: "Dr. Duisberg's masterly exposition of the splendid results achieved by the combination of German chemistry, German enterprise and German capital has been a delight and revelation to us all." Now carefully note these foresighted words of Little to which not enough heed was given, as we now only know too well. Said Little, mind you, thirty years ago: "We have in this country the capital, the enterprise, and I fully believe, the chemistry as well, required for equally great industrial achievements. That we can not thus far point to them is due to the fact that with us chemistry is too often left like Cinderella sitting beside the ashes of the laboratory furnace, while her two haughty sisters drive away together to the industrial ball. But some day, not far distant, her Prince will come and lead her forth to take her proper place before the world. . . . He will be wise in that chemistry which deals with men as well as learned in the chemistry which deals with things. He will be a Doctor of Chemical Organization, and we must not be surprised if his degree reads C.O.D." Little had the faculty of introducing a pun in his most serious remarks.

Now what was the expression of opinion on that beautiful large synthetic rubber tire that was unfolded for the first time and caused such consternation to William Henry Perkin, Professor of the university at Manchester, England, who happened to be one of those present at the Duisberg lecture. For hadn't Professor Perkin been the first to prepare "dipentene" in a synthetic way, a stepping stone to produce real rubber? Professor Perkin thought that Duisberg was taking too much credit for all these achievements, and plainly told him so. This resulted in a heated discussion that almost reached the stage of World War I. Perkin referred to his own father, the great Sir William Henry Perkin, as the founder of the chemistry which made such things possible, and reminded Duisberg that Germany to make artificial rubber on a large scale would need to depend upon England for a source of its raw materials.

The Duisberg tire was said to be the spare of a set of tires of artificial rubber that were prepared for the imperial automobile of Kaiser Wilhelm II. The rubber was prepared from "isoprene." The isoprene was derived from paracresol, which as a matter of fact was purchased from England. The process became known as the Elberfelder process, but today paracresol is not needed to produce isoprene. There are less expensive and more convenient ways of preparing isoprene.

An Englishman by the name of Wil-

liams discovered isoprene in breaking down natural rubber (caoutchouc) by heat distillation, and in 1860 observed that the isoprene, which is an oily liquid, thickened up with long contact with the air. In 1879 a Frenchman by the name of Bouchardat not only found that isoprene would, upon standing, slowly change into a rubber-like substance, but under certain definite conditions this change could be hastened by treatment of the isoprene with hydrogen chlorid gas. Tilden of London, in 1860, had tried the same thing but with somewhat discouraging results. Wallach, in 1887, found that light hastened a change of isoprene to the rubber-like mass. Harries, a German, in 1902 found that isoprene, when heated to 200 degrees Centigrade temperature, would yield dipentene (a double isoprene molecule), and other syrupy liquids. This was considered a stepping stone to producing real rubber. Dr. Fritz Hofmann, at Elberfeld, found in 1909 that by heating isoprene for eight days at a temperature of 120 to 200 degrees Centigrade, rubber could be formed. Later Hofmann found a still better rubber could be gotten by employing a lower temperature, namely, that of boiling water, and what is known as a catalyst, an activating chemical agent that hastens the reaction to a matter of days. To a Russian chemist, J. Ostramislensky, belongs most of the honor of working out the chemical structure of caoutchouc, and the related synthetic rubbers, three decades ago.

Artificial rubber tires were produced in the United States for the first time less than two years ago, according to recent news reports. The B. F. Goodrich Company, Akron, Ohio, is given the credit for producing the very first U. S. synthetic rubber tire, which was introduced in the market on June 5, 1940. The synthetic rubber used in these tires is produced differently from that used in the Elberfelder tire, and is said to have equal if not superior wear resistance to that of natural rubber. The synthetic rubber used by Goodrich is known as *ameripol*, which is attracting most attention at the present time for vast quantity production.

The world to-day turns its attention to producing synthetic rubber from the cheapest raw materials; petroleum in the United States, brown coal in Germany, and alcohol from potatoes in the Union of Socialist Soviet Republics. Extensive equipment is of course needed to carry out the chemical reactions, together with many fine chemicals of which there is needed an abundant supply. Some day we may all be riding around in our motor cars on artificial tires, made of synthetic rubber, and we will not need as many renewals as we did before, because the tires will have lasted much longer. At present the military needs must come first.

THE HISTORY AND BEHAVIOR OF A COLONY OF HARVESTER ANTS

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THIS paper primarily concerns observations on a single colony of the California red harvester ant, *Pogonomyrmex californicus* (Buckley), which is in the author's garden in Pasadena, California. The nest, like most others of the species, opens on nearly level ground through one or rarely more holes of considerable size (up to one-half inch or more in horizontal diameter and somewhat less in vertical diameter). Each of these is near one side of a broad, low mound, usually less than a foot in diameter, formed of earth and grains of sand brought up from the cavities below. As described by Wheeler[2] and Cole,[3] such mounds are much smaller than the great accumulations of sand and gravel gathered by the Texan harvester, *Pogonomyrmex barbatus* (Smith) and the western harvester, *P. occidentalis* (Cresson), yet considerably larger than the insignificant craters of *P. subdentatus* Mayr and *P. apache* Wheeler. During a brief part of one summer when the colony was exceptionally large, the particularly extensive accumulation of earth surrounding the hole was penetrated by galleries and chambers containing larvae and occupied by numerous ants, which ran out when the mound was disturbed so that the system of cavities partly collapsed. The structure thus showed an approach to that of the western harvester, which normally builds a large cone full of chambers.[2] At all other times, however, the mound was solid and excavations were below the surface of the ground.

Unlike the Texan and western harvesters, no large cleared area is maintained around the entrance of the nest by the California harvester ant, but there is a tendency to remove or restrict small plants growing close to it. Thus on June 27, 1940, and on subsequent days several ants were seen biting at various parts of a small plant of pimperel growing beside the hole. They were able to remove the tender tips, which were dropped to the ground and discarded, and thus prevented the plant from growing larger.

Prior to approximately 1924, no harvester ants were seen in the area where the nest under consideration now exists, although colonies a few blocks away were noted. However, in the summer of 1924 or the one immediately preceding it, four or five workers were seen at various times, although none were traced to the nest. The next summer more workers were found, as well as the small nest opening surrounded by a low mound of sand two or three inches across. During the next three or four years the colony grew rapidly, moving somewhat from season to season. During the years 1927 to 1931 it was as large as any colony of the species which I have observed, and it was during these years, probably as a result of the extensive subterranean tunnel system, that seasonal movements of the nest openings were greatest. The

[1] I am indebted to Dr. T. H. G. Aitken, Mr. B. Brookman, Dr. E. G. Linsley and my wife, Mary H. Michener, for reading of the typescript of this paper and for offering numerous valuable suggestions concerning it. Especially, I wish to express my appreciation to my mother, Mrs. H. Michener, for continued encouragement in this and other studies, as well as for numerous notes on the early spring and late fall activities of these ants.

[2] W. M. Wheeler, "Ants," xxv + 663 pp. (see especially pp. 284–293). Columbia University Press, 1913.

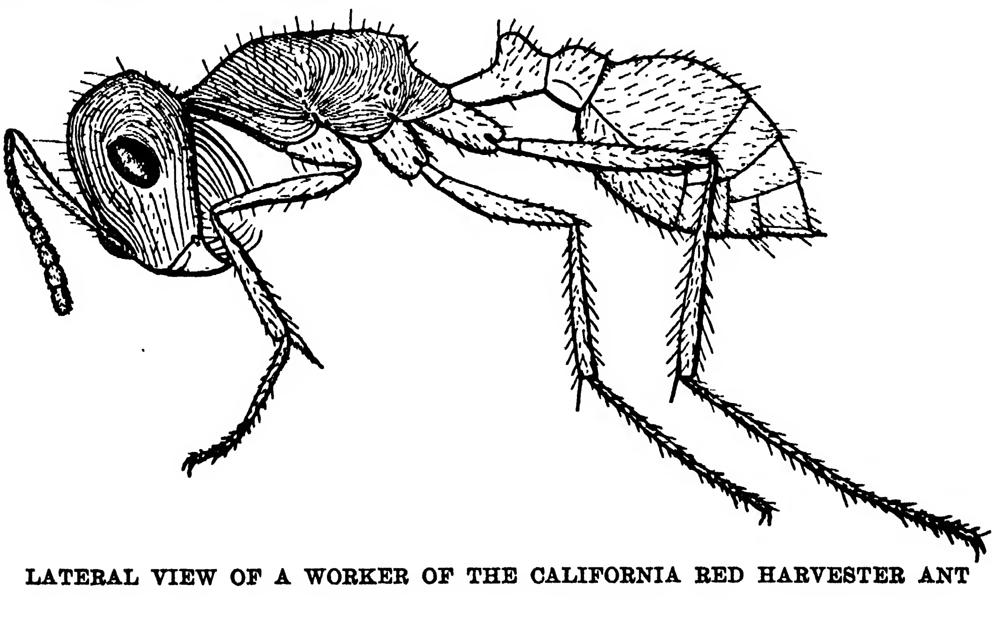
[3] A. C. Cole, *Ent. News*, 43: 113–115, 1932.

activities of a horned toad, *Phrynosoma coronatum blainvillii* (Gray), resulted in great depletion of the colony during the warm parts of the summers of 1932 and 1933. The lizard would lie beside the nest opening and eat the ants as they moved in and out. Its excreta seemed to consist almost entirely of ant parts, all of which came from this nest. By the fall of 1933, the colony was again small, but at this time the lizard disappeared. Since then the ants have increased moderately in number. Their failure to reach the abundance of the 1927 to 1931 period is, I believe, to be explained by recent environmental changes in the area involved. The California harvester is typically an ant of more or less open, sandy, dry, grass- and weed-covered areas. We have altered the environs of this colony by irrigation and by the planting of many shrubs and small trees, so that considerable areas previously available for seed collecting are now useless. The soil has never been as sandy as that in which this ant is normally most abundant. At the present time (July, 1940), the colony, approximately sixteen years old, seems to flourish even though not maximum in size, and I see no reason why it should not continue to do so, barring further human interference.

Seasonal History

The seasonal rhythm in this species is marked. From early November until February or March the nest is closed, although active individuals can be found by digging down a few inches at the site of the previous year's opening. In 1930 the nest was closed for the winter a few days before November 11, and was first opened on March 22; in 1934 it was opened about February 21, and in 1940 about March 22. Both in early spring and late fall the number of individuals outside of the nest on the surface of the ground is much smaller than during the warmer parts of the year.

In the spring the first opening to the surface has always been made within four or five inches of the previous summer's entrance. The early spring activities of 1940, the year in which they were observed most fully, will be described at some length. On each reasonably warm day during the period from February 22



LATERAL VIEW OF A WORKER OF THE CALIFORNIA RED HARVESTER ANT

until March 15, a very few, or sometimes as many as thirty or more harvesters could be seen wandering slowly and apparently aimlessly in the vicinity of last year's nest opening. Many of these were attacked or killed by Argentine ants, *Iridomyrmex humilis* Mayr. It is probable that activity on the part of all these harvesters was forced upon them either when a bird scratched deep enough in the soil to open the nest or when Argentine ants which were digging on the site of the previous year's harvester nest opening broke into the nest and allowed a few harvester ants to crawl up to the surface. Apparently none of the *Pogonomyrmex* which emerged from their nest during this period were able to return to it. However, on March 16, a warm day, a group of forty or fifty ants was seen around the mouth of each of two small tunnels in the vicinity of last year's nest opening. These ants stayed in compact groups, moved very sluggishly, and did no work. It is not certain whether they or the Argentine ants made the tunnels. Many of the harvesters were killed by Argentine ants, but some returned down the shafts, which were just large enough for them to pass through. From March 17 to 21 the weather was again cool and few ants were seen, but on March 22 and 23 some harvesters made two or three small openings barely large enough for them to crawl through with difficulty. Their activities were similar to those of the ants observed on the sixteenth except that some were seen scratching the soil with their fore legs, a process which will be described later; they showed no interest in seeds. Most of them returned into the holes, which were subsequently closed. From March 25 until April 10, another cool period, no harvesters were seen except those which chanced to emerge through Argentine ant holes. On April 11, another warm day, harvesters appeared at about ten tiny holes, some of their own making, some excavated by *Iridomyrmex*. They wandered about for a short time, then most of them returned to their colony; although they scratched with their fore legs, seeds did not interest them. By April 14 a larger opening had been made, a few objects were carried out of the nest, and although no ants went far from the nest opening or appeared to search for food, seeds placed near the opening were picked up and carried in. Cool weather subsequent to April 16 again stopped all apparently voluntary outside activity. Within a few weeks, however, a normal colony entrance appeared. It is thus seen that the commencement of activity in the spring is a gradual process, as is also the cessation of activity in the fall. Twice in early spring two major openings four or five inches apart were made at approximately the same time. Once one of these was closed in a few days, on the other occasion both remained in use for several weeks.

A new tunnel is usually made to the surface a month or two after the original openings appear in the spring. This second entrance is immediately enlarged, and in a day or two a typical mound surrounds it. In 1931 the new opening was made on May 15. On one occasion, when the colony was very large, ants were observed working after dark around the secondary opening for a day or so after its formation. This is in contrast to the usual closing of the hole before dark and is of interest in connection with Cole's[3] observations on nocturnal activity in the Mojave Desert. After a week or more during which both openings are in use, the primary one is permanently closed, the secondary opening being used exclusively. The distance between primary and secondary openings varies with the size of the colony. When it was large, as in 1929, the secondary opening was nine feet from the primary, while when it was small, as in 1934, it was only about

one and one-half feet distant. The total area in which openings have been made during the sixteen years of life of the colony is about 240 square feet.

Occasionally at almost any time of the summer a new opening may be made a few inches or even two feet from the one in regular use, and sometimes as many as four openings may exist at the same time within a few inches of one another, each with its own typical mound. Normally all but one of these will be gradually abandoned and in the course of a few weeks permanently closed. Except for the brief period in the spring already mentioned, I have but rarely seen two entrances more than a foot or two apart in use at the same time.

During the spring, usually until several days after the secondary opening has been made, most of the ants' activity outside of the nest is immediately around the openings. Bits of sand or earth are carried out and deposited on the mound, and many ants walk around and over the mound. Little or no food is collected, although seeds are accepted and carried into the nest if placed near the opening; few or no ants go more than a few feet from the nest entrance. After this time the ants wander more widely and bring seeds and other food to the nest in increasing quantities through the summer. During September and October activity gradually decreases, the working portion of the day becomes short, the number of ants seen outside is reduced until finally no ants appear at all, and the nest is closed for the winter.

Swarming: Although actual swarming has been observed but rarely, many winged females and a few males are observed each summer to come to the entrance of the nest or even to walk out into the sunlight for an inch or more, only to return. By far the largest swarm that I have seen was on July 12, 1929, a clear, warm day. About the usual number of workers was foraging away from the nest. At 9:30 A.M. queens and males were as abundant as the very numerous workers, running over the ground in an area about one foot in radius surrounding the nest opening. This region actually appeared red with ants. The males started to leave, at first slowly then more rapidly (up to about fifty per minute), flying upward from the area around the nest and disappearing against the sky. When they had nearly all gone, but before the rate of departure had decreased, females began to fly upward in a similar manner and in equally great numbers. Females in particular apparently need a high point from which to start their flight, climbing everything available. Nine were seen on one small stick standing about two inches upward from the surface of the ground. By 10:30 A.M. almost all the queens were gone, and by 11:00 A.M. no winged ants were in sight; most of the workers which had covered the ground around the nest had returned to it, so that activity was normal. For several weeks before and after swarming, queens were seen at the nest entrance; perhaps those seen afterwards left in an equally large swarm later in the year, but it seems more probable that one or several smaller groups departed during the course of the summer.

Two days after this great swarm, two dealated queens were found, each in a small shaft sunk about an inch into the ground. Neither survived to produce a new colony.

On July 15, 1939, from 10:05 A.M. (before which the nest was not observed that morning) until 10:35 queens left the nest at a rate of one or two per minute. Workers were very numerous on the ground near the nest. No males were seen, perhaps because observation was not started early enough. Many of the females instead of flying returned to the nest, and a few additional ones left the next day, which, like the preceding, was hot and clear.

Another swarm, similar to the last, was noted on June 27, 1940, a clear, warm day. It did not stop until about 11:00 A.M. Females departed at the rate of about six per minute. As usual, some alates were seen at the nest entrance on subsequent days. By the beginning of August no such alates were seen. Although Wheeler[2] reports a swarm before May 23 in the desert regions along the Colorado River, it is doubtful if alates are found so early in Pasadena.

Daily Activities

The daily activities of the ants are those most easily observed and most fully known. The nest opening is closed each night and reopened each morning throughout the warm part of the year. The evening closure in Pasadena takes place between sunset and dark in midsummer, before sunset in spring and fall, while the morning opening takes place sometime after sunrise.

The actions of the ants on a typical, hot, clear, July day will be described in some detail in order to exemplify the usual course of activity. The observations upon which this account is based were largely made on July 28, 1928, several days in July in 1929, and July 14 to 16, 1939, and have been verified and augmented by numerous incidental or brief visits to the nest.

The ants begin to open their entrance hole about 6:45 A.M., shortly after direct sunlight strikes their mound. Ants within dig and push their way out through the plug at the mouth of the hole. Sometimes as a result of digging from within, a part of the plug will cave in on some of the ants, and a number of dust-covered individuals will crawl out, followed by clean ones which must have been farther from the scene of the collapse. By alternate scratching movements of the fore legs, assisted by the mandibles for larger objects, the ants which have come out gradually increase the size of the opening by distributing the material of which the plug is made over the surrounding mound. At this time on a warm day, the temperature, taken by laying an uncovered thermometer on the ground beside the nest, has reached about 82° F. On a cool, foggy morning the hole may not be opened until 7:30 or 8:00 A.M., and then at a temperature of 70° F. the ants are very sluggish in their movements. On one occasion when the colony had two openings about two feet apart, one was shaded by bushes in the morning for about an hour longer than the other. The shaded one was not usually opened until nearly half an hour later than the other on sunny mornings, although on foggy mornings the two were opened at the same time. From the time the nest is opened until about 8:00 A.M. on a sunny day, many ants work around the nest carrying various small sand grains, bits of earth and other objects out of the hole and dropping them near the margin of the mound. At about 8:30 A.M. ants begin to walk away from the nest in search of seeds and other food. They leave in all directions, never in a trail; yet their wanderings are not entirely aimless. As observed on many occasions, the majority collected seeds from bird traps some fifty feet from the nest. In order to get there they followed the garden path around two sides of a square rather than taking the direct route across rough ground and among plants. During the summers of 1939 and 1940 no seeds were kept at this location, and the ants radiated much more evenly over the surroundings, picking up weed seeds and the like. Individual ants followed from the nest to the source of food and back did not follow exactly the same route on the return that they had taken on the way out; often the two would be as much as six or eight inches apart. (Further notes on the movements of the ants and results of experiments concerning their

mechanism of orientation will be given in a subsequent section.) Ants were never seen over one hundred feet from the nest and rarely that far. Many apparently carry nothing on their return journey; perhaps they have minute objects in the mandibles or infrabuccal chambers. By 9:30 A.M. they become less active, fewer going out of the nest; by 10:00 A.M., with a temperature of 121° F. on the ground, few leave the nest, although a considerable number are still returning from their morning's foraging trips. By 10:30 A.M. none are returning from or leaving on long journeys, although a few run rapidly around the vicinity of the nest opening, getting as far as a couple of feet from it. The temperature at the surface of the ground at this time is about 129° F. All the ants in sight during the hot part of the day run at a much more rapid rate than when the ground is cooler. By 11:00 A.M. only one or two ants are in sight at a time and these never get more than a foot from the nest opening, to which they quickly return. Never is any attempt made to close the nest at midday, in contrast to Cole's[3] Mojave Desert observations on this species. From 11:30 A.M. until 12:30 P.M. ants come out only an inch or two from the opening and remain in the sun only a few seconds at a time. The temperature at the ground surface is then about 133° F.

If at such a time an ant is taken some distance away from the nest, it will rush about at a tremendous speed, climbing each pebble or stick it reaches and hesitating in such places above the hot, level surface before descending and running until another elevation is found. If kept down on the ground level, the ant will die in less than one-half minute.

Gradually as the temperature lowers in the afternoon, more ants become evident, wandering farther from the nest opening, so that by 1:40 P.M., with the temperature about 125° F., seven or eight ants are often visible at one time. By 2:30 P.M., when the temperature has fallen to 115° F., many ants are leaving and entering the nest and going long distances for food as in the morning. This continues until about 4:30 P.M., when the number on long excursions decreases considerably. By this time the temperature is about 90° F. and the ants move much less rapidly than when it is hotter. About 3:30 P.M. considerable numbers of ants begin to congregate around the mound at the nest entrance, going in and out of the hole and carrying various objects around more or less erratically, often seemingly without much reason.

At 4:40 P.M. closing of the nest opening for the evening has already begun, and by 4:50 P.M. a good many ants are working on this. The technique used is to scratch very rapidly (or less rapidly as the temperature drops) with the front pair of legs in the fine dust around the hole while walking slowly forward on the middle and hind pairs of legs. When a grain of sand one-fourth to one millimeter in diameter is uncovered in this process, it is grasped in the mandibles, carried to the opening of the hole and there dropped. At 5:40 P.M. the opening is about half closed, and only thirteen or fourteen ants are left working outside. Progress is slow, the number of ants outside decreasing to five or six at 6:15 P.M., when the opening is about three-fourths closed. At 6:30 P.M. the work is complete and only three or four ants are outside. The number of ants visible at various times during the closing process varies slightly from season to season. The numbers just given were those of July 28, 1928. During July, 1939, more ants took part in the closing activities, and on July 14, 1939, twelve ants were left outside when the hole was closed, the largest number I have ever seen. The ants which finish closing the nest and remain outside continue occasional er-

ratic scratching until long after dark. From dark until about 9:30 P.M. about half of those outside wander aimlessly and slowly, one by one, to weeds growing a foot or more away and often climb up as much as an inch into them, there spending the night. The other half of the group remains at the entrance of the hole until morning. As the temperature goes down, activity almost entirely stops, a condition reached slightly above 65° F. In the morning when the nest is opened, those ants which spend the night at the entrance and at least some of those which wander into the weeds remingle with other members of the colony. I have often seen the nest at night when no ants were in sight and am inclined to believe that during most of the year, especially the cooler parts, those ants which stay outside, if any, are very few in number and all go into the weeds or other protection for the night or are killed by the Argentine ants.

On cool or overcast days during the summer, the nest may not be opened until 8:00 A.M. or even later, and activity continues unabated through the middle of the day.

The shortening of the daily periods of outside activity in spring and fall is much greater than would be expected. Thus on April 12, 1940, with the temperature on the surface of the ground as high as 125° F., the ants were active for only a couple of hours at midday, closing their small holes at a time when the thermometer read 95° F. From such a state of feeble activity they gradually change to the point in midsummer where the nest is open, although the ants are sluggish, at temperatures as low as 65° or 70° F. As fall approaches, the period of activity is again shortened more rapidly than the decrease in length of the days. Thus on September 7, 1939, a clear, warm day, the nest was opened at 8:45 A.M. and closed at 2:30 P.M., the early closure perhaps resulting from late afternoon shading by bushes. The next day it was closed at 3:00 P.M., even though the temperature of the ground surface was then 91° F. On September 9, the hole was opened at 9:00 A.M., when the temperature was 83° F. A brief period of lower temperature resulting from clouds caused the nest to be closed, but it was reopened at 10:00 A.M. when the ground temperature was 98° F. Other observations made in the fall indicate that the shortening of the daily period of activity is general, and that it continues gradually to a point where the nest is not opened at all.

As will be seen from the preceding descriptions, the activities of the ants at any time of the year are well correlated with the temperature of the ground surface. The seasonal differences in the temperature at which certain activities take place are perhaps related to the temperature below the surface, which varies with the total amount of heat absorbed and radiated and would be expected to be higher in midsummer when the days are long than in spring and fall, even though the surface temperatures during these seasons might be the same for certain periods of the day.

In connection with these observations, Cole's[3] notes on the habits of the species in the Mojave Desert are interesting. The hot climate there seems to affect the events of the day considerably, for he says: "Harvesting activity seems to be confined to the early morning and late evening hours. Many of the ants even work at night. During the heat of the day I found the entrances of all nests of *californicus* closed with sand or pebbles. When nests were opened under these conditions, the ants were from one to a few feet below the surface where the soil temperature was noticeably lower." Since Cole gives neither time of year nor ground temperatures, it is impossible to correlate these observations well with those made in the cooler climate of Pasadena.

The high temperatures at which *Pogonomyrmex* works to best advantage are doubtless correlated with the fact that this is a genus of primarily desert insects, which probably originated in a dry area and now occurs in regions characterized by aridity and hot summers in both North and South America. Pasadena is probably considerably cooler in summer, and perhaps moister, than most areas in which these harvesters occur.

As already stated, the movements of the California harvester are most rapid when the ants are very hot. When cool, as in morning or evening or on many spring and fall days, harvesters are comparatively sluggish. At such times, as pointed out by Shapley[4] and Tulloch,[5] the small introduced Argentine ants, which are active day and night, torment the harvesters greatly as they work around the nest. The ants which close the opening in the evening are particularly hampered by *Iridomyrmex*. Should a harvester come upon an invading Argentine ant, the former will often grasp the smaller ant in its mandibles, and curling the abdomen under the thorax, sting the intruder to death and drop it. When the temperature is low, however, the harvesters are commonly too clumsy to do this successfully. The usual thing is for the Argentine ants to cling by means of their mandibles to the legs and antennae of the *Pogonomyrmex*. This greatly disturbs, the latter, especially if several of the smaller ants attack a single harvester in this way. Individuals of *Pogonomyrmex* may eventually be killed by the Argentine ants. When the temperature at the surface of the ground rises above 85° or 90° F. the Argentine ants cease activity so that the harvesters are not bothered by them during the time of day that the latter are most active.

The primary food of the California red harvester is seeds of almost any kind small enough for a single individual to carry. Rarely if ever do two or more cooperate in carrying food of any kind to the nest, no doubt primarily because foraging trips are essentially solitary activities. Bird droppings are often carried into the nest, as are also dead and injured insects. Food dropped at the entrance of the nest is readily accepted. Often if a pile of seeds is placed there, some are carried away from the hole instead of into it; bits of meat or injured insects are immediately attacked with great vigor by many ants, whose first act, apparently, is to suck some of the liquids from such food. Later, or even as this process goes on, the pieces of food are broken up and carried into the nest. Seeds are apparently recognized as food only when touched or nearly touched by the antennae. Ants whose antennae were cemented to the head by fine flour paste or by water putty wandered over seeds without giving any evidence of recognition, but if one antenna were freed and if it touched a seed, the ant would immediately pick it up.

INDIVIDUAL BEHAVIOR AND ORIENTATION

As has already been stated, these ants do not follow any recognizable trails as does the Texan harvester, but each individual follows a somewhat different route away from the nest. An ant leaving the nest usually travels more or less directly for a certain distance, often many feet, after which it wanders apparently at random over a considerable area until it finds a seed or other object to be taken back to the colony. It then grasps this object in its mandibles and returns more or less directly to the nest on a route which is almost always at least a few inches from that of the outward journey. Should there be two or more entrances to the nest, the ant normally returns to the one from which it

[4] H. Shapley, *Psyche*, 27: 72–74, 1920.
[5] G. S. Tulloch, *Psyche*, 37: 61–70, 1930.

emerged, although if on its return journey it happens to cross the mound surrounding another, it will usually enter that opening. When one of two or more open holes is permanently closed, it often happens that for two or three days thereafter a few ants will be seen scratching around the entrance of the recently closed hole as they would if it were to be opened from below as usual in the morning. By marking with fine powder numerous ants returning to the nest from one side, it was found that their next trip from the nest, which often started in less than a minute from the time they entered after being marked, might be in any direction. There was no tendency, even if they had taken a single seed from a large pile of seeds, to return in the direction from which they had just come. For this reason there is little concentration of ants around a pile of seeds placed in a given locality; only those individuals which happen to blunder upon it take seeds. Nevertheless, there is a certain tendency for ants to go to a region in which there is a regular supply of seeds, as around the bird traps already mentioned, rather than to places where seeds are scarce.

In view of the facts presented above, the problem of how the ants find their way back to the nest becomes interesting, and in July, 1940, several experiments were performed in an attempt to determine the answer to this question. When an ant is given a seed, it almost invariably takes it and starts to go directly toward the nest. Therefore, by presenting an ant with a seed one can be quite certain of having given it a strong urge to go to the nest. This fact has been used extensively in these experiments.

On a number of occasions an ant returning to the nest with food was allowed to start to walk across a sheet of paper, and while on it was moved a considerable distance, often to a place on the other side of the nest. It was thus possible to transfer the ant without disturbing it to such a degree that its reactions could not be counted upon. Always, if the new location were within the area normally covered in foraging trips, the ant changed its direction and traveled toward the nest without hesitation from the new position. If a barrier, such as a board on edge, were placed on the ground between a returning ant and the nest, the ant would go around the board, showing evidence of seeing it when four or five inches away, and start directly toward the hole from the changed position. It is thus clear that the direction of light has little or nothing to do with the orientation of the ants, for if it did they would continue in their old direction when artificially transferred from place to place.

Several ants, either having seeds or given seeds after being moved, were transferred, as described above, to places about eighty feet away from the nest and well outside of the region in which the ants were in the habit of working. There, except as discussed below, they wandered erratically, still carrying their seeds. If after a few minutes they were returned to a point in the region where foraging ants normally work, they immediately went directly toward the nest opening. This suggests that they orient themselves by memory[6] of certain features of the region with which they are familiar.

Two of the individuals which were carried about eighty feet away were taken almost directly from the entrance of the nest and probably belonged to the large class of individuals which come out of the nest for only a few inches, then turn and go back into it. Given seeds, they took them, but soon put them down and explored the vicinity, each fre-

[6] Memory is here used in the sense of series of conditioned responses, that is, as differential behavior with respect to present stimuli as a result of previous experience with the same stimuli.

quently returning to its seed, from which it made progressively longer and longer trips so that in three minutes from the time they were given seeds the ants were going as far as one and one-half feet from their seeds. Brought back to the vicinity of the nest, they showed no facility in finding it. This is probably an indication of some sort of division of labor among the workers; possibly the younger ones work around the colony, only one older ones going out to collect food. It gives further evidence that memory[6] of the surroundings may be the means by which the ants find their way back to the nest.

On one occasion seeds were sprinkled in an area about fifteen feet from the nest. Then a band four feet in width between the seeds and the nest was cleared and the top half inch of soil removed so that its distinctive appearance and odor must have been totally changed. Ants which had gone out before this clearing was done found seeds and returned with them, without hesitation crossing the cleared area. This indicates that their ability to return directly to the nest is not dependent on characteristics of the odor of the surface of the ground or the appearance of the smaller objects on the ground, but may perhaps depend upon memory of large objects, such as bushes and the like, a number of feet away.

In order to test this idea further, the bottom ($3\frac{1}{2} \times 2\frac{1}{2}$ feet) of a rectangular, wire-screen cage (one-half inch mesh) was covered with paper and then with a thin layer of soil. The screen at the sides would cause little interference with vision and would permit ants in the cage to see possible landmarks outside. An ant, given a seed, was allowed to walk onto the bottom of the cage via an incline of dirt or was transferred to the cage on a piece of paper. It would start through the cage toward the nest. The cage was then lifted off the ground and turned through any angle. While still off the ground, the ant would change its direction with respect to the cage and continue toward the nest. It was impossible, even with repeated rotations, to cause the ant to lose its direction, and when finally the ant walked out of the cage, it continued to the nest. This experiment was repeated several times with different ants with similar results.

On the other hand, when the sides of the cage were covered with paper and the ends similarly covered except for the lower three inches (so that an ant inside could see only the unfamiliar bottom of the cage, the paper walls, small openings at the ends of the cage and the sky above), ants with seeds would continue toward the nest when first introduced into the cage. However, after one or two 90° or 180° turns of the cage, and not until such turns, they lost their direction, sometimes wandering irregularly, more often walking back and forth the length of the cage. If allowed to walk out under the paper walls, they immediately oriented themselves properly and went to the nest. This shows that no odor or sound emanating from the nest could guide the ants back to it, because the ants inside the cage with paper walls presumably would have perceived these as easily as those in the open cage or outside on the ground.

Finally, a number of ants found well away from the nest while apparently searching for food were picked up with a pair of forceps, and their eyes covered with thin flour paste or water putty, which dried to form a thick, opaque covering. After being held for a few minutes until the substance on the eyes dried, the ants were put down on the ground near where they were found. For five to fifteen minutes ants so treated acted very abnormally, running around irregularly, refusing to pick up seeds, and trying to scrape the covering off their eyes. After that period of read-

justment and struggling, they stopped at seeds offered them. Most refused to pick them up, but two did so and carried them about, wandering aimlessly. These ants were again picked up and the coverings chipped off their eyes. After a period of adjustment following handling similar to that described above, they accepted seeds offered them and carried them directly to the nest. As controls to this experiment, similar coverings were placed on parts of the body other than the eyes of several ants. After a period of adjustment following being picked up, they were able to carry seeds directly back to the nest. An ant with only one eye covered could find the nest satisfactorily.

These experiments seem to indicate that this species of ant is guided in its foraging excursions largely by its sight, presumably by its memory of rather large objects some distance from its line of travel, and not to any large degree by stimuli perceived through other receptors. Cole's[3] observations on nocturnal foraging, however, suggest that the ants may under some circumstances find their way without the use of much light. According to Forel and Wasmann, the antennal sensillae are the chief receptors of information concerning location and are of importance in the homing of many ants. Nevertheless, these authors state that certain ants make use of their eyes as well as their antennae in finding their way, and *Pogonomyrmex* appears to be an extreme case of specialization in this direction, perhaps resulting from the long association of species of the genus with windy deserts, where the aridity, shifting soils and widely scattered food supply make odor a poor guide. It is interesting to note that the eyes of workers of *P. californicus* are rather large for ants although smaller than those of *Formica,* and each consists of about three hundred ommatidia.

Summary

Observations on a colony of harvester ants (*Pogonomyrmex californicus*) in Pasadena, California, have shown that for three or four months during the winter the nest is continually closed and that during the remainder of the year it is closed every night. Outside activity goes on only during the warmer parts of the days. The actions of the ants are well correlated with temperature; they are sluggish at 70° F., exhibit maximum foraging activities with temperatures at the surface of the ground between 90° and 115° F., and are driven into the nest except for very brief excursions by temperatures over 120° F. Swarming occurs more than once each season, during the late mornings of certain clear, hot days in June and July. The introduced Argentine ant (*Iridomyrmex humilis*) is a serious pest of the *Pogonomyrmex*. Although the harvesters apparently perceive seeds, which are their chief food, through antennal sensillae, it appears likely that they are guided in their foraging excursions, notably in finding their way back to the nest, largely by the use of their eyes.

Note: The colony of harvester ants discussed in this paper did not open its nest in 1941, after a winter of rainfall far heavier than that experienced for many years and nearly twice the average. The same was true of certain other colonies in the region, one of which, according to the report of the owner of the property on which it was situated, was at least forty years old.

SCIENTIFIC RELATIONS BETWEEN EUROPE AND AMERICA IN THE EIGHTEENTH CENTURY

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THE American colonies were settled in an age which witnessed a tremendous growth of interest in science. Its utilitarian significance was immediately appreciated in a world that emphasized middle-class values. But, apart from its meaning for the advancement of business enterprise, science had its followers who looked to it for guidance in unearthing the secrets of the universe. It has largely been a joint enterprise from the seventeenth century on, and to the layman as much as to the academician in these early years is due the accumulation of masses of scientific and near-scientific data. To mention one instance, plans were made for English and American groups to make a cooperative study of vegetable colors, and in general to aid each other in the study of natural history.[1] In a retrospect of the eighteenth century, a writer in a popular magazine observed that an international scientific correspondence prevailed and that in the promotion of utilitarian devices "the world is but as one Family." "The scientific theorist and the practical labourer have shaken hands and minted into one common stock the result of their labours."[2]

Scientists began writing in the vernacular thus reaching a larger audience. Condorcet strongly urged the abandonment of Latin, and the number of books on natural history written in the classic tongue declined rapidly in the eighteenth century. In writing for the populace care was taken to avoid technical language and, when necessary, authors took pains to define even simple terms. One of the first great popular successes was Buffon's "L'Histoire Naturelle" which sold over twenty thousand copies and was to be found scattered over Europe and America.[3] Linnaeus was informed that books on natural history sold better than any others in England.[4] In America the more popular channels of scientific communications were the newspapers and the almanacs, the latter reaching an annual circulation of many thousands.[5] The magazines extracted articles from the *Philosophical Transactions* of the Royal Society and thus reached a vastly larger group. The Newbery publishing house, so famous for its children's books, saw to it that even very young readers were informed on physics, motion, water, fire, vision, etc. There must have been a keen demand for these publications, for some of them ran into several editions.[6]

Lectures were widely attended in America and Europe, with women as well as men in attendance. Dr. Henry Moyes was in America in the 1780's and

[1] J. E. Smith, "A Selection of the Correspondence of Linnaeus and Other Naturalists," London, 1821, Vol. 1, Dr. A. Garden to Charles Whitworth, April 27, 1757. Hereafter cited as Smith.

[2] *Gentleman's Magazine*, 1800, pp. 1273–74.

[3] D. Mornet, "Les Sciences de la Nature en France au xviiie Siécle," pp. 2–4, Third Part, Chap. I.

[4] Smith, Vol. I, April 16, 1747.

[5] See C. E. Jorgenson, *New England Quarterly*, 8: 555–561; on almanacs in Europe, see Preserved Smith, "A History of Modern Culture," Vol. 2, p. 391.

[6] Charles Welsh, "A Bookseller of the Last Century," p. 302. London: John Newbery, 1885.

it was reported from Philadelphia that "people of every description, men and women, flock to the lectures. They are held at the University three evenings a week."[7] In a work published for the use of school children the latter were advised to "make it a rule to see for [themselves]."[8]

Americans were to be found on the rolls of many European societies who welcomed contributions from overseas in the advancement of science. Europeans, on the other hand, considered it a great honor to be elected to membership in the American Philosophical Society.[9] Count Rumford, an exile from his native America after the Revolution, established medal awards by the Royal Society and the American Academy of Arts and Sciences for leading contributions in heat and light. He was, incidentally, the first winner of his own award in England.[10]

War itself was held to be no bar to an exchange of scientific communications between antagonists. Joseph Willard, writing from Harvard during the Revolutionary War to the secretary of the Royal Society, maintained that "political disputes should not prevent communications in matters of mere science"; he did not see how any one could "be injured by such an intercourse."[11] During the earlier war between the French and English, naturalists in both countries had an understanding to return specimens that had been captured by enemy warships.[12] The bitter conflict with the government of the French Directory did not prevent an English captain from extending courtesies to a scientist returning from America with a vast collection of plants, and he was permitted to run the blockade.[13]

In the large commercial warehouses were gathered goods from the ends of the earth, and here and there among the products of trade could be found curiosities—fossils, sea shells and what not—all calculated to provoke the imagination. Merchants stole time from more prosaic pursuits to write letters which transported them to distant realms. Peter Collinson, the London merchant and naturalist, writing to John Bartram, the Pennsylvania botanist, apologized for the repetition in some of his letters; "a multitude of affairs divert my memory, and my letters are not worth copying—being mostly writ behind the counter."[14] There were many of the type of Collinson who were included in the membership of the scientific societies then rapidly spreading over Europe. From the start these organizations revealed a cosmopolitan outlook. One of the earliest, established at Rome in 1600, had a plan to locate groups everywhere in the world for scientific cooperation. Among its publications was a "Thesaurus Mexicanus," a description of plants and animals in Mexico.[15] Other societies founded on Italian models followed their lead.

The most famous of these organizations was the Royal Society in England. Its influence was world-wide, and its publication, the *Philosophical Transactions*, was the most distinguished forum avail-

7 William Darlington, "Memorials of John Bartram and Humphry Marshall." (Philadelphia, 1849.) Mary Norris to Marshall, February 23, 1875. Hereafter cited as Darlington.

8 "Botanical Dialogues between Hortensia and her Four Children . . . for the Use of Schools." By a Lady (London, 1797), with a commendatory letter by Erasmus Darwin, p. 229.

9 *Transactions of the Society . . . for the Encouragement of Arts, Manufactures and Commerce* (1789), Vol. 2, p. 361; *Cal. of Franklin Papers*, Vol. 2, J. Ingen Housz, Vienna, November 19, 1783, M. Defaÿ, January 12, 1784, Wm. Herschel, February 18, 1787.

10 G. E. Ellis, "Memoir of Sir Benjamin Thompson, Count Rumford," pp. 241, 246, 250–258.

11 *Philosophical Transactions*, Vol. 71, February 16, 1781; see also Franklin's letter to Alexander Small, Passy, July 22, 1780, in Smyth, "Benjamin Franklin, Writings."

12 Smith, Vol. 1, "Ellis to Linnaeus," May 31, 1757.

13 *Gentleman's Magazine*, 1798, p. 716.

14 Darlington, p. 134 (September 2, 1739).

15 M. Ornstein, "Scientific Societies in the 17th Century," pp. 74–76.

able to scientific opinion. The Royal Society sought information on the natural history and physical condition of foreign lands and to that end a correspondence with other societies was early established. This correspondence was read at the meetings, and it made the Society more of an international than a local English group; "every important experiment, every important article, was communicated to it almost as soon as it was published."[16] French, German and Russian societies were likewise established before the first quarter of the eighteenth century was over. Not until the second half of the century were similar organizations formed in English America, although many years earlier Increase Mather had gathered together with a small group fairly regularly to discuss philosophical problems and to add "to the Stores of Natural History."[17]

Although organized efforts in behalf of science came comparatively late in the colonies, individual initiative, in cooperation with European societies, made up for this lack. Secretary Oldenberg wrote to John Winthrop, the earliest American member of the Royal Society, when asking for communications: "You will please to remember that we have taken to taske the whole Universe, and that we were obliged to doe so by the nature of our Dessein. It will therefore be requisite that we purchase and entertain a commerce in all parts of the world with the most philosophicall and curious persons to be found everywhere." Four years earlier, Oldenberg had confidently written Winthrop that the Society expected from him a better description of "the remarkables (of New England) than is any yet extant, concerning the mappe of the country, the history of all its productions, and particularly of the subterraneous ones . . . likewise a relation of the Tides upon your coast, together with the course of your rivers, but especially and above all, a full account of your successe in your new way of salt-making, whereof we could not compasse the experement here, as was much desired." Oldenberg joined with Winthrop in ridiculing "the notional and disputaceous school philosophy" and urged him to foster "this reall Experimental way of acquiring knowledge, by conversing with, and searching into the works of God themselves"; the youth of New England should be "seasoned and possesse[d] with the same."[18] Oldenberg urged that a natural history of New England be written. Years later the grandson of Winthrop was honored by the dedication to him of a volume of the *Philosophical Transactions* for his numerous contributions to mineralogy.[19]

From the lips of Dutch merchants returned from Brazil to their native Amsterdam, a young German student, George Marcgrave, heard stories that aroused his curiosity so that he was given a place in an expedition to South America in 1638. Here he stayed for several years making observations of all kinds and gathering large collections of the fauna and flora of Brazil. Although he died before he could put his material in shape for publication, others took up the task. De Laet, of the West India Company edited some of Marcgrave's work which appeared in Leyden under the title, "A Natural History of Brazil." In this book appeared more than six hundred and fifty forms, nearly all new to science, some four hundred of them were figured from the drawings left by Marcgrave. When Count Maurice, leader of the expedition, returned to Holland, he brought back a collection

[16] Ornstein, pp. 124, 127; *Philosophical Transactions*, passim.

[17] K. B. Murdock, "Increase Mather," pp. 147–148. Cambridge, 1925.

[18] Massachusetts Historical Society, *Proceedings*, ser. 1, XVI, 211, October 13, 1667; August 5, 1663; March 26, 1670.

[19] Vol. 40; see long dedicatory notice to John Winthrop, F.R.S., August 15, 1741.

so rich in specimens that he had enough for his own museum and those of other private individuals, besides supplying two universities. By common consent of leading authorities, Marcgrave is accorded a high place for his contributions to ichthyology: he made known to scientists over one hundred new fish. Four charts of Brazil done by Marcgrave were etched on copper by the order of Count Maurice, and copies of these were to be seen on the walls of aristocratic Dutch homes.[20]

The comparatively few efforts of the seventeenth century were to be multiplied in the next, and systematic coordinated scientific activity in several fields may be noted. The contributions of American members, now a larger group, to the Royal Society's "Transactions" were continued, and among the most active of them was Cotton Mather.[21] Individuals of equal or lesser fame sent their communications abroad and the publications of several European societies paid tribute to American activity.

This energy was mainly expended in the field of natural science, with especial emphasis on botany. It is no mere coincidence that great progress should have been made in botany when a new floral world was revealed to the European investigator. The thousands of specimens, hitherto unaccounted for, stimulated students to remarkable efforts. What is one of the earliest books on North American plants appeared in 1635, by J. P. Cornut, "A History of Canadian Plants," describing those which had been brought back to Europe. Not long after, John Josselyn, the traveler in New England, described its native plants and other "rarities." Josselyn included a list of plants introduced by the English, and like other observers he noted that while some transplanted products fared worse in America the greater number were "bigger and better" in the colonies.[22] The observations and collections of John Banister, of Virginia, engaged as a missionary in 1680, were catalogued in the "History of Plants" by Ray, eight years later.

Contemporary with Banister, William Vernon of Cambridge University and Dr. David Kreig made a trip to Maryland for botanical specimens which eventually came into the possession of Hans Sloane. Vernon looked forward on his return to a weekly discussion of the new specimens with Sloane and some other cronies.[23] Mark Catesby stayed in several colonies for a number of years under the patronage of several noted botanists. He wrote frequently to his patrons, keeping them informed of his travels in "one of the Sweetest Countrys I ever saw" (South Carolina), and sent them large quantities of plants and seeds.[24] On his return in 1726 Catesby began work on his massive publication, celebrated by an eighteenth century historian as "the most splendid of its kind that England had ever produced."[25]

In the work of the leading botanists of this period may be traced the new world contributions. To professional botanists the period from 1694 to 1735 is known as the "Tournefortian Period" after the author of one of the most important

[20] E. W. Gudger, *Popular Science Monthly*, 81: 250, 1912.

[21] G. L. Kittredge, American Antiquarian Society, *Proc.*, Vol. 26, n.s., p. 23; Kittredge, *Colonial Society of Massachusetts, Publ.*, Vol. 14; Theo. Hornberger, "American Literature," Vol. 6.

[22] John Josselyn, "New Englands Rarities Discovered," . . . pp. 85, 90, London, 1672; F. Mood, *Colonial Society of Massachusetts, Publ.*, 28: 24*ff*.

[23] British Museum, Sloane mss., 4037, July 24, 1698.

[24] Royal Society Library, mss., Sherard Letters, Vol. 2; Catesby to Sherard, 163–185, May 5, 1722–January 10, 1724–25.

[25] Richard Pultney, *Historical and Biographical Sketches of the Progress of Botany in England* . . ., Vol. 2, Chap. 44, pp. 55–57, London, 1790. Other American contributions are mentioned in Vol. 2, pp. 276–278.

books in botany. While Tournefort's debt to investigators in North America was large, the obligations of Linnaeus, who gave his name to the next period in botanical science were far greater.[26]

At a meeting of the Royal Swedish Academy of Sciences, Linnaeus suggested that some one be sent to North America to collect seeds of plants which would "improve the Swedish husbandry, gardening, manufactures, arts and sciences." Peter Kalm, who was chosen for the task, not only published his travels, but raised many of the seeds he collected in his private garden, while others were cultivated in the Botanical Garden at Upsala. Linnaeus, in his "Species of Plants," carefully noted the findings of Kalm. He further enriched his knowledge by a visit to the collections of Sir Hans Sloane and Mark Catesby, much of which had been gathered in North America.[27] In all, Linnaeus described some two thousand plants, and animals to the hundreds from North America in his "Species of Plants" and "System of Nature."[28] After visiting a garden in Amsterdam, Linnaeus wrote to a friend: "We are all devoted to the love of exotic plants, especially those from America."[29] The heavy indebtedness of Linnaeus' "System of Nature" (in its last edition) to Dr. Alexander Garden of South Carolina, was noted by other scientists: "no name occurs there more frequently" said one authority.[30] From every part of the world new and rare discoveries are brought to your door, wrote Collinson to Linnaeus, "your agents bring you tribute from every quarter."[31]

Expeditions came over to America from Vienna and from Italy, but the most important was probably that of André Michaux sent over by the French government in 1785. Michaux traveled all over the country and sent back to France over sixty thousand living woody plants and many boxes of seeds. His publications too, were of the first importance in the literature of natural history.[32] Michaux worked in friendly rivalry with an Englishman, John Fraser, who was also in South Carolina seeking out plants and grasses useful to his homeland. Fraser returned home with thirty thousand dried specimens of plants, as well as some living plants, and a new grass for meadow land or pasture. He also wrote a book in which he acknowledged the important assistance given him by Thomas Walter, a local resident. Without books or learned collections of natural history, Walter, said Fraser, "made his descriptions with an accuracy that is allowed to be by no means inferior to the most eminent botanists in Europe."[33] It is worth noting that a study of foreign plants stimulated a closer examination of native products.[34]

While Linnaeus and other European students benefited directly by investigations of fellow countrymen traveling abroad, they also felt obligated to Americans with whom they corresponded. No American was held in higher esteem than the self-taught Quaker, John Bartram.

[26] P. A. Rydberg, *N. Y. Botanical Garden Contribs.*, Vol. 4, No. 100.

[27] Catesby correspondence in Sherard letters in Royal Society Library, mss., Vol. 2, May 5, 1722, Dec. 9, 1722; see elaborate publication by Catesby, "The Natural History of Carolina, Florida and the Bahama Islands" (2 Vols. 1731–1743); Edward Edwards, "Lives of the Founders of the British Museum" (London, 1870, 2 Vols.), section on Sir Hans Sloane.

[28] Rydberg, *loc. cit.*: J. A. Allen, *Annals of New York Academy of Sciences*, Vol. 18.

[29] Smith, Vol. 2, to Albert Haller, May 1, 1737; see also Rydberg, *Science*, Vol. 26 (1907), pp. 66 *ff*.

[30] *Transactions* of the Linnaean Society (1791), Vol. 1, introductory discourse by J. E. Smith: also Smith, Vol. 1, Garden to Linnaeus, June 2, 1763. Garden was elected to Royal Society at Upsala.

[31] Smith, Vol. 1, April 10, 1755.

[32] F. Brendel, *Amer. Naturalist*, Vol. 13.

[33] John Fraser, "A Short History of the Agrostis Cornucopiae: or the new American Grass" . . . , pp. 3–5, London, 1789.

[34] *Cf. Memoires de l'Academie Royale des Sciences* (1701), p. 209.

He was wholly devoted to his researches, writing simply, "I love Natural History dearly." To an English correspondent he wrote, "I am often exposed to solitary and difficult travelling, beyond our inhabitants, and often under dangerous circumstances, in passing over rivers climbing over mountains and precipices, amongst the rattlesnakes, and often obliged to follow the track, or path of wild beasts, for my guide through the desolate and gloomy thickets."[35] All the first rate botanists in Europe were acquainted directly or indirectly with Bartram's work. In the letter just quoted, he also wrote: "To my friends Doctor Dillenius and M(ark) Catesby, I sent my observations on such things as will be proper materials to assist them in composing their fine histories, for which they promised me one of their books." Dr. J. J. Dillenius, professor of botany at Oxford, deferred printing his "History of Mosses," till he could see what Bartram, Clayton and John Mitchell might send from America.[36] John Frederick Gronovius of Leyden, then printing a new edition of one of his works, wrote to Bartram: "You shall find [therein] the names of all the minerals and fossils you ever had sent to me, with an encomium and thanks of all the benefits You have bestowed upon me."[37] Bartram urged Gronovius to write in English: "I can make but a poor hand of Latin."[38] Philip Miller, superintendent of the Chelsea Garden, whose "Dictionary of Gardening" was the best known work of its kind, and was used as a model for the first American book on the subject, was another who enriched his collections because of Bartram's activity. The Garden at Chelsea displayed many of the specimens sent over by Bartram who in turn received numerous contributions from Miller.[39] Through Collinson Bartram was employed by a number of patrons on an annual basis to furnish them with seeds and plants. In the 1750's he was supplying some fifteen patrons, including the Prince of Wales, at a charge of five guineas each. Of three hundred new American plants introduced into England after 1734 (down to 1776) Collinson was responsible for forty, most of which came from Bartram: two hundred or so were credited to Philip Miller, many of which had likewise been sent over by Bartram. The latter, it may be mentioned in passing, was one of the first to produce hybrid plants, then called "mules."[40]

Within less than half a century, said Catesby, America "has furnished England with a greater variety of trees than has been procured from all the other parts of the world for more than a thousand years past."[41] A society was formed in Edinburgh to import American seeds (subscribers to pay two guineas each) and to draw up a catalogue of American and Canadian plants and trees which could flourish in Britain: a correspondence was also to be maintained with Americans interested in botany.[42]

The work of others besides Bartram was gratefully remembered by European contemporaries. Cadwallader Colden's catalogue of plants found on his New York estate was published by Linnaeus in the transactions of the Academy of Sciences at Upsala. The proficiency of

[35] Darlington, Bartram to Collinson, April 23, 1746; May 26, 1742; see also letter of Lewis Morris to Collinson, *N. J. Hist. Soc. Coll.*, IV, May 24, 1742.

[36] See G. C. Druce, "The Dillenian Herbaria" . . . Oxford, 1907, and J. J. Dillenius, "Historia Muscorum," p. viii. London, 1768.

[37] Darlington, July 2, 1750.

[38] Gibson mss., IV, 21, Friends House, London.

[39] N. G. Brett-James, "The Life of Peter Collinson," pp. 108–109.

[40] Peter Collinson, mss. "Note Book," British Museum Natural History; Ernest Earnest, John and William Bartram, chap. 4, and page 38. Philadelphia, 1940.

[41] Catesby, "Hortus Europae Americanus" . . . preface. London, 1767.

[42] *Scots Magazine*, February, 1764, p. 83, August, 1765, p. 395.

his daughter, Jane Colden, attracted attention abroad. Peter Collinson wrote Linnaeus that she was the only woman he had heard of who was "scientifically skilful in the Linnaean system," and he recommended her example "to the ladies of every country."[43] The "Virginia Flora" published by Gronovius was based on observations made by Clayton, and a later edition included the work of Colden, Mitchell and Kalm as well. John Mitchell, of Virginia, was credited with important discoveries and his name was especially drawn to the attention of Linnaeus.[44] Mitchell was at work for a long time on a comprehensive natural and medical history of the colonies. It was a lonely effort for Americans widely scattered along the seacoast and in the back country, wanting in books and in stimulating companionship. They sought out one another and craved the stimulation of the European botanical fellowship.[45]

Humphry Marshall, a younger cousin of John Bartram, was also in correspondence with Europeans and his book on American trees and shrubs received the stamp of scientific approval by translations for foreign students. John C. Lettsom was interested in forming a group to subsidize Marshall for a year to gather specimens from American woods and mountains. He told Franklin he was already sponsoring a European naturalist then traveling through America.[46] Marshall's "Arbustum Americanum" (1785) was the first strictly American botanical work, written by a native American and printed in this country. It was republished in Germany where foresters believed that the more rapidly growing American trees, if transplanted, might augment the dwindling supply of German timber. Wangenheim, a critical student of American woods, planted on his estate in Thuringia, a section of forest land which he called "America."[47] William Bartram, son of John, was a skilled naturalist who knew how to portray in words and colors the phenomena he met with in his expeditions to the southern colonies. Sponsored by Dr. Fothergill, Bartram spent five years in these regions and sent collections and drawings to his English Maecenas.

This interest in natural history was not restricted to the scientifically elect; it was a fad in which nearly all classes of society satisfied the desire to collect things. Collinson wrote to Bartram: "There is a [great] spirit and love of [gardening and planting] amongst the nobility and gentry, and the pleasure and profit that attends it, will render it a lasting delight."[48] Some of the nobles who could afford it literally transplanted a bit of America to England. Collinson described the collection of Lord Petre, a patron of Bartram: "The trees and shrubs . . . are grown to great maturity. Last year Lord Petre planted out about ten thousand Americans . . . which make a very beautiful appearance. When I walk among [his nurseries] one cannot help thinking he is in North American thickets, there are such quantities."[49] Collinson's own garden was internationally famous and its rarities were shared with many botanists. His contagious enthusiasm awakened the love of gardening among many young men of means. In retrospect he once remarked, "I often stand with wonder and amazement when I view the incon-

[43] Darlington, p. 20; "Jane Colden," in N. Y. Botanical Garden Contribs., Vol. 4, no. 88; Smith, April 30, 1758; Smallwood, "Natural History and the American Mind," p. 92.

[44] Smith, Collinson to Linnaeus, Vol. 1, January 18, 1743–44; Vol. 2, Mitchell to Linnaeus, April 16, 1747; Smallwood, p. 123.

[45] John Nichols, "Literary Anecdotes of the Eighteenth Century," Vol. 1, p. 483 note. Dr. A. Garden to Dr. J. Parsons, May 5, 1755.

[46] Jared Sparks, "Franklin's Writings," Vol. 10, p. 267, August 14, 1786.

[47] Pennsylvania-German Society, *Proceedings*, 7: pp. 28–29.

[48] Darlington, April 24, 1751.

[49] Darlington, September 1, 1741.

ceivable variety of flowers, shrubs and trees now in our gardens, and what there were forty years ago."[50] Dr. John Fothergill wrote to Linnaeus, "Our Collinson taught me to love flowers, and who that shared his comradeship could do other than cultivate plants?" Bernard de Jussieu, professor of botany at the garden of the French king, told Dr. Thomas Bond, an American visitor, that he would feel at home among so many of his native plants which had been brought from America by the professor himself.[51] The Sloane Herbarium and the Herbarium of Joseph Banks (both of which were incorporated in the British Museum) were enriched by plants sent over by Bartram, Catesby, Mitchell, John Clayton and lesser botanical explorers.[52] Books and articles were written to give instructions on the proper methods to pack and send plants from America, and in the 1780's a magazine was established to display in natural colors the foreign specimens cultivated in England.[53] An English author, J. R. Forster, who felt that the work of Gronovius made other compilations unnecessary, nevertheless wrote his book for he thought that English readers should learn about American plants in their own language.[54]

Botanical studies expressed esthetic as well as utilitarian objectives. But husbandry was almost entirely a practical matter. The advances made in the seventeenth century, largely under Dutch influence, were as halting steps compared with the giant strides of the next one hundred years. The achievements of Bakewell, Townshend and Jethro Tull helped revolutionize agriculture, and societies for the dissemination of their views were familiar institutions in England and America. Americans shared with Englishmen in the awards given for improvements in agriculture and the mechanical arts by the London Society for the Encouragement of Arts, Manufactures and Commerce.[55] Postmasters in New York and Charlestown actively propagandized in behalf of the London society.[56] Italian reformers also followed American proposals for promoting agriculture.[57]

Arthur Young, editor of the "Annals of Agriculture," and chief preceptor of the new agriculture, had for his schoolroom America as well as the British Isles.[58] George Washington was an eager disciple, and the notes he assembled from Young's publication and Tull's "Horse-hoeing Husbandry" indicate his indebtedness. Young taught him soil conservation and sent to Washington English plows and various types of seeds. In his last annual message as President, Washington recommended the establishment of a board of agriculture to award premiums and assist generally

[50] L. W. Dillwyn, "Hortus Collinsonianus," Swansea, 1843. p. vii: N. G. Brett-James, *op. cit.*, pp. 106, 225.

[51] Darlington, February 20, 1739.

[52] E. Ray Lankester, ed., "The History of the Collections contained in the Natural History Departments of the British Museum," Vol. 1, pp. 81, 83, 140. London, 1904.

[53] J. C. Lettsom, "The Naturalist's and Traveller's Companion" (London, 1772), had a third edn., 1799: Wm. Curtis, *The Botanical Magazine* . . . in which . . . Foreign Plants . . . will be accurately represented in their natural Colours . . . (London, 1787); I looked through ten volumes of Curtis' publication which contains many American plants.

[54] J. R. Forster, "Flora Americae Septentrionalis, or a Catalogue of the Plants of North America . . . in their Different Uses, and the Authors who have Described and Figured them" (London, 1771).

[55] Wm. Bailey, "The Advancement of Arts, Manufactures, and Commerce, or Descriptions of the useful machines and models contained in the repository of the Society for the Encouragement of Arts, Manufactures and Commerce" . . . (London, 1772, Vol. 1).

[56] "American Letter Book 1773–1783," p. 24, Anthony Todd to Foxcroft and Finlay at N. Y., June 1, 1774. Ms. in General Post Office, London.

[57] "Opuscoli Scelti sulle scienze e sulle arti," tomo 10, p. 321, Milan, 1787.

[58] "Letters from . . . George Washington to Arthur Young," London, 1801, especially August 6, 1786.

in diffusing information on the latest improvements. This proposal clearly followed the example of the English Board of Agriculture and revealed once more the influence of Young and Sir John Sinclair.[59] Sinclair, president of the English Board of Agriculture and correspondent of Washington and other distinguished Americans, had proposed such a plan to embrace all Europe and the United States, and his hope was that scientific communications would be exchanged among the agricultural departments of every nation.[60] Rewards made up of a fund subscribed to by every country, were to be given to those making useful discoveries in "Rural Economy" as well as in medicine and the "Useful Arts." In addition to the immediate practical advantages for science and industry that Sinclair expected would result from this international correspondence, he hoped too, that it would promote the cause of peace.[61] Americans participated in the debates on the merits of various fertilizers that filled the pages of Young's publication. They were very enthusiastic (at least for a time) over the effect of plaster of Paris on rejuvenating their worn out fields. Americans acknowledged the superiority of English husbandry, but they too felt capable of aiding its progress, especially in the invention of agricultural machinery. News came to Young from Philadelphia of a machine for threshing and cleaning grain in one operation delivering six bushels an hour "fit for the miller."[62] Benjamin Gale of Connecticut was awarded a prize by the London Society for the Encouragement of Arts for his improvement of the drill-plow.[63] Jared Eliot, the best informed writer on agriculture in colonial America wrote his own "Essays" because American conditions were so different from those in the mother country that books for English farmers were of little use overseas. He complained too, of the clumsy apparatus devised by Tull for drilling, and immediately set to work to make a simpler and more efficient machine.[64] Eliot's "Essays" were known abroad where advanced agriculturists held them in admiration.[65] American apples already had a market in England where they were esteemed above the native product.[66]

Strikingly modern ideas were bandied about. A Parisian correspondent asked Franklin's opinion about a primitive incubator.[67] A Frenchman projected an incubator and a Scotsman anticipated present day horticulturists by suggesting the possibility of accelerating vegetation by electricity.[68] But it was an uphill struggle for the reformer. As in England, so in America, wrote one to Young, "prejudices in favor of antient modes are laid aside with difficulty."[69]

None of the phenomena of nature so stirred the European in America as did the sight of new birds and animals. No European commentary was complete without reference to the beauty of the humming bird or the fascinating horror of the rattlesnake. Poets rhapsodized over the humming bird and the mocking

[59] P. L. Haworth, "George Washington, Country Gentleman," Indianapolis, 1915, Chap. 5; "The Correspondence of Sir John Sinclair," Bart. (1831, 2 Vols.), p. xxiv, Vol. 1, p. 279.

[60] Young, *Annals of Agriculture*, Vol. 27 (1796), pp. 42–48.

[61] Sir John Sinclair, "Plan of an Agreement among the Powers in Europe, and the United States of America, for the Purpose of Rewarding Discoveries of General Benefit to Society" (London, 1795).

[62] *Annals of Agriculture*, Vol. xvii, pp. 206–207.

[63] *Cal. of Franklin Papers*, II, December 10, 1770.

[64] R. H. True, *Agricultural History*, October, 1928.

[65] Smyth, "Franklin's Writings," Vol. III, to Eliot, December 10, 1751.

[66] Darlington, Letter of Michael Collinson, February 25, 1773.

[67] *Cal. of Franklin Papers*, II, November 25, 1773.

[68] *London Magazine*, February, 1747; R. H. Fox, p. 69.

[69] *Annals of Agriculture*, Vol. xix, p. 245.

bird, and veracious witnesses testified to the power of the rattlesnake to charm the unwary. English and Scottish newspapers attested to the general curiosity about rattlesnakes and other American fauna. A Boston correspondent wrote to the Royal Society of a local frog as big as a "*Penny loaf*," "which cries exactly like a *Bull.*"[70] John Bartram sent over to Fothergill large bull frogs and playfully suggested they be put in St. James Park pond where they "would surprise & divert all the adjacent inhabitants of London" but on second thought he believed Kew Gardens would be better as "being more private."[71]

Several correspondents sent to the Royal Society their descriptions of American moose, pigeons and whales. The Society wanted from Cotton Mather a study of the relationship of winds to the migration of pigeons. He was asked for additional information (with which he was always ready) about the "Mouse Deer": "what we have hitherto had," said the Society, "being very imperfect & not to be depended on."[72] On the subject of whales, Paul Dudley wrote with scientific understanding, but emphasized particularly their economic value: "I am Endeavouring after a short natural history of our whales," he told Dr. Jurin. Within a few months he sent a fascinating description of the spermaceti whale and the nature of ambergris.[73] An attractive publication by George Edwards, "A Natural History of uncommon Birds and of some other rare and undescribed Animals" (1743–1751) owed considerable to American students of ornithology: he was aided too, by observing live specimens in London. In another work Edwards spoke of the importation of large numbers of the painted finch, either for gifts or to be sold.[74]

It was regretted that no satisfactory description or collection of the fish and insects of America had been made and to answer that need "The American Oracle" by Samuel Stearns included a section on the animals of North America listing some one hundred and fifty birds.[75] For the more learned there were numerous articles on American phenomena in the Philosophical Transactions. Franklin had already asked John Bartram to do what he alone was best fitted to achieve . . . the writing of a "natural History of our country."[76] Benjamin S. Barton's writings on natural history were known abroad where special notice was taken of his observations on the connection between the migration of birds and seasonal changes.[77] Jefferson, then minister to France, helped educate the Count de Buffon in American natural history, and ordered specimens to be sent over from Virginia.[78]

Naturalists in Europe and America were deeply interested in the fossils discovered in the Ohio Valley, although half a century earlier Cotton Mather had sent to John Woodward, paleontologist and secretary of the Royal Society, bones and fossil teeth.[79] One supposition was that the huge animals arriving at the salt licks in a wet season "sank so deep as not to be able to rise out & the others out of Sympathy or some other Cause not being willing to leave their Com-

[70] Benj. Bullivant, January 15, 1697–98, Royal Society Library, mss., B.2, 46.

[71] Bartram mss. letters, November 28, 1769, British Museum of Natural History.

[72] Royal Society Library, mss., W.3, 77; W.3, 79, 1713; M.2, 35, June 21, 1714.

[73] Royal Society Library, mss., D.1, 80, October 3, 1724; D.1, 85, April 5, 1725.

[74] George Edwards, "Gleanings of Natural History" . . . , pp. 132–133. London, 1758.

[75] "The American Oracle," pp. 331–338; (London, 1791), see statement on the need for such a work, *European Mag.*, Vol. 12, p. 274.

[76] Darlington, January 9, 1769.

[77] *The Monthly Review, or Literary Journal*, enlarged series, Vol. 36, p. 351.

[78] "Jefferson's Writings" (Monticello edition), to A. Cary, January 7, 1786, December 23, 1786.

[79] F. E. Brasch, *Scientific Monthly*, Vol. 33 (1931), pp. 348–349.

panions in distress have shared the same fate.'"[80] George Croghan, the Indian trader sent to Collinson some fossil teeth, and a close examination was made by the distinguished anatomists John and William Hunter, of some bones sent to the Royal Society. It was concluded that they were not the bones of an elephant, as had been imagined, but of a different kind of animal.[81] On comparing the teeth sent over by Croghan with those from Asia and Africa, Collinson concluded they were "what is called Mammot's Teeth from Siberia."[82] Franklin made similar observations and then went on to note the fact that "elephants now inhabit naturally only hot countries, where there is no winter, and yet these remains are found in a winter country; which looks as if the earth had anciently been in another position, and the climates differently placed from what they are at present."[83] Jefferson was anxious that "very exact descriptions" be made of these finds but he warned against premature theorizing: "the moment a person forms a theory, his imagination sees, in every object, only the traits which favor that theory." More facts must be collected, he insisted, before theories could be advanced as to these fossil finds.[84]

Within a short time fossils were added to the geological division of the British Museum, and as was the fashion in popularizing science in the eighteenth century, books for the general public referred to these finds. Jedidiah Morse's "American Geography" noted Jefferson's observations that the skeleton indicated an animal much larger than an elephant.[85] Fossils as well as minerals and "curiosities" were exchanged between the Royal Museum at Copenhagen and Yale College, and a proposal was made by the Prince of Parma to swap specimens so that Italian and American museums might thereby be enriched.[86] The discovery of fossils opened up many questions, particularly of identification —whence had they come? The conflicts between the Rationalists and the old order were accented by this problem for it separated more sharply those who defended and those who attacked the tradition of Genesis.

A large part of the history of scientific interrelations between Europe and America in the latter half of the eighteenth century can be written around the personality of Benjamin Franklin. It is quite impossible to appreciate the amazing diversity of his contacts with science, and the confidence its students placed in him, unless one reads the thousands of letters written to him and by him. Individuals on both sides of the Atlantic refrained from publishing till he had criticized their work, and a writer was happy indeed could he send forth his book dedicated to Franklin. He was one of the most important channels through which Americans and Europeans kept abreast of each other's achievements. He saw to it that scientific instruments for Americans were made by the best English and Scottish manufacturers. He was better known abroad than at home, said the *Scots Magazine;* look in the foreign publica-

80 Thomas Hutchins to Brigadier General Haldimand, Nov. 15, 1768, "Journal from Fort Pitt to the Mouth of the Ohio in the Year 1768," Brit. Mus. Add. mss., 21686 (f. 39–42).

81 *Phil. Trans.*, 57, 464; 58, 34; *Memoires de L'Institut National de Sciences et Arts,* tome 2 (1796), pp. 1–23; *Stralsundisches Magazin,* 1768, pp. 179–189; other German and Italian publications referred to these fossils.

82 Darlington, Collinson to Bartram, May 17, 1768.

83 Smyth, Franklin to Croghan, August 5, 1767.

84 H. F. Osborn, *Science,* new ser., 82, 533–538.

85 E. Ray Lankester, *op. cit.*, pp. 200–201; Morse, p. 55 (1798, 3rd edn.); Wm. Guthrie, "A New Geographical Historical and Commercial Grammar . . . ," pp. 899–900, (1798, 17th edn.).

86 Ezra Stiles, "Diary," February 7, 1787; *Penn. Mag. of Hist. and Biog.*, Vol. 28, Jefferson to Peale, June 5, 1796.

tions on electricity, it urged, where will be found on almost every page the terms Franklinism, Franklinist and the Franklinian system. He was, said one English biographer, the "American Newton."[87]

Collinson first made Franklin's name known to the English when he published in book form some of the letters his American correspondent had written on electricity. Within a few months, Collinson was writing in excited exaggeration: "All Europe is in agitation verifying electrical experiments on rods."[88] Franklin's experiments early commanded the attention of the curious everywhere, and for the better instruction of a non-English reading public translations of his writings were rapidly made. Supporters of his lightning rods were more numerous in America than in Europe, but during his stay abroad in the decade of the 70's, Franklin encouraged their wider adoption. From London he wrote to Professor Winthrop of Harvard, one of his firmest supporters, that he had answered the questions of Nevil Maskelyne, the Royal Astronomer, relating to lightning rods: "I have likewise given sets of directions for erecting them to several persons who desired it." "I purpose to follow your advice," he continued, "and draw up a more compleat instruction to workmen than I have yet given, to be inserted in the Magazines. St. Paul's Church is now guarded . . . and many gentlemen's houses round London are now furnished with conductors." Winthrop replied that he had spoken and written in advocacy of lightning rods: "they are now becoming pretty common among us."[89]

A pamphleteer was confident that Englishmen would rapidly take to conductors, but as the Revolution approached political passions divided scientists on this question.[90] A magazine recommended to the inhabitants of St. Bride's, London, Winthrop's letter criticizing the repair of a church steeple without using a conductor: "Philosophy, we fear, in vain lifts up her still and gentle voice, and unavailingly calls out across the Atlantic."[91] Jean Baptiste Le Roy urged the French to use the rods, and Franklin proudly noted that in Tuscany and in Venice they had been erected.[92] The Austrian Emperor put conductors upon gunpowder magazines as well as other structures, and that thunderous figure of the French Revolution, Robespierre, appears more prosaically in correspondence with Franklin asking advice, so that as a lawyer he might argue with intelligence the question of the legality of lightning rods. Voltaire's example in putting a rod on his own house reassured many of the timid.[93] In later years during his stay in France letters came to Franklin from all over Europe requesting advice in the construction of lightning rods.

Frederick E. Brasch has written on the close relations that existed between the Royal Society and its correspondents in the colonies who supplied some of the data basic to the structure of eighteenth century science. Newton, wrote Cotton Mather to the Society, was "the *perpetual Dictator* of the learned World."[94] Massachusetts seemed to the distant Londoners a field for research with especial promise. The earth and the seas and

[87] *Scots Mag.*, Vol. 45 (1783), pp. 174–176; same article in *European Mag. and London Rev.*, Vol. 3 (1783); *Gentleman's Mag.*, 60, 572.

[88] *Cal. of Franklin Papers*, Vol. 2, Sept. 27, 1752; *Phil. Trans.*, 47: 202–211, 289, 565–67.

[89] Mass. Hist. Soc., *Proc.*, Vol. 15, Franklin to Winthrop, June 6, 1770, October 26, 1770.

[90] Benjamin Wilson, "Considerations to prevent Lightening from doing Mischief" . . . (June 24, 1764), Brit. Mus. Add. mss. 30094 (f. 106), *ibid.*, (f. 238).

[91] *The Monthly Review or Literary Journal*, Vol. 42 (1770), pp. 199–210. London.

[92] Smyth, Franklin to Winthrop, July 25, 1773.

[93] *Cal. of Franklin Papers*, Vol. 2, January 29, 1777; Smyth, 1: 9, 104, 105.

[94] Royal Society Library mss., to Richard Waller, M.2.29 (letter 2).

the heavens too, were probed for their secrets. Franklin, half seriously, urged Sir William Herschel to come to America where skies were brighter and the chances for astronomical discoveries thus greater. In gratitude for his election to the American Philosophical Society, Herschel sent a catalogue of one thousand new nebulae and clusters of stars.[95] But long before Franklin, Americans were adding to the store of astronomical knowledge.

In the seventeenth century Thomas Brattle's observations on the comet of 1680 (Halley's comet) were made use of by Newton. Paul Dudley, whose contributions to the Royal Society were nearly always written in a truly scientific spirit sent a history of New England earthquakes.[96] Cadwallader Colden and James Alexander sent several observations of the "Eclipse of the first Satellite of Jupiter . . . in New York for determining the Longitude of that place." They had already determined its latitude.[97] Andrew Oliver, Jr., of Massachusetts, received an appreciative and critical response from Joseph Priestley to whom he had sent his "Essay on Comets."[98]

Probably the ablest scientist in America, and Newton's most distinguished disciple this side of the Atlantic was Professor John Winthrop, of Harvard. He contributed some eleven papers to the Royal Society and his studies ranged from seismological disturbances to observations on the transits of Venus in 1761 and 1769. One of his correspondents was James Bradley, astronomer royal, to whom Winthrop wrote modestly, but confidently, of his researches, leaving to him the decision to publish a work on comets.[99] David Rittenhouse, of Pennsylvania, added to the value of the cooperative studies of the transits of Venus in which English and French astronomers joined.[100] The volume published by the American Philosophical Society containing the papers on the transit of Venus was reviewed with enthusiasm in England, and American frankness and openness in giving full details of their research were commended as an example to "those European Astronomers, who are so very *shy* of giving particulars."[101] Franklin's explanation of the aurora borealis was hailed as one of the first to be based upon the "sound principles of reason and philosophy."[102]

Studies of wind and weather obviously had great usefulness in an age of sailing ships, and Americans joined enthusiastically in compiling the valuable data. Spurred on by the ailing Cotton Mather, Isaac Greenwood, then Hollis professor at Harvard, offered to send the Royal Society an annual meteorological account of New England. He proposed to send over accounts of eclipses, for he had good instruments, he wrote, and his advanced students would also aid him. Greenwood suggested that societies in London and Paris get extracts from the journals of sea voyages and reports from sailors on winds and weather: "it is not impossible that we should be able to make a probable Judgment of the Effect and Influence of the Wind upon the

95 Sparks, "Franklin's Writings," Vol. 6, p. 569, Feb. 18, 1787.

96 Royal Society Library mss., D.1, 94, November 13, 1727.

97 Royal Society Library mss., Classified Papers, VIII, 1, 76, August 9, 1723.

98 Mass. Hist. Soc., *Proc.*, 2nd ser., Vol. 3, pp. 13, 14, February 12, 1775.

99 Royal Society Library, Bradley mss. 44 (f. 147) September 21, 1761; *ibid.*, 46 (f. 4) April 18, 1760 (f. 18), May 19, 1760; F. E. Brasch, "Newton's First Critical Disciple in the American Colonies—John Winthrop," in Sir Isaac Newton 1727–1927, History of Science Society.

100 Rittenhouse's death was mourned abroad. He was America's greatest astronomer, said C. D. Ebeling, *Amerikanisches Magazin*, Vol. 1, Part 3, 1796, p. 165.

101 *Gentleman's Magazine*, 41: 416–417.

102 *London Review of English and Foreign Literature*, 11: 233–36.

Weather."[103] These joint observations were to lead to the composition of a history of the weather, a project which was apparently approved by the Society. A writer in the *Gentleman's Magazine* asked that Americans keep systematic tables of meteorological observations which might explain the manners, customs, diseases and "the fall of countries." Proper tribute was paid to the work of Dr. Lining, of Charlestown, in this field, but much more was hoped for, especially from college presidents in the colonies.[104] An international meteorological society founded at Mannheim, 1780, had members in nearly every European country, Greenland and the United States, whose observations were printed in many volumes.[105]

News of Thomas Godfrey's invention of the sea quadrant was sent to Halley from Philadelphia by James Logan. Thomas Pownall, once governor of Massachusetts, where he had learned much of value for North Atlantic navigation, contributed an important paper to the Society, "Hydraulic and Nautical Observations on the currents in the Atlantic ocean." Some of his information came from Franklin, and other sources were American shipping masters who, thought Pownall, were superior to European masters and thus made "shorter & better passages." Quoting Franklin, Pownall said the speed of Nantucket ships westward bound was nearly equal to that of voyages from America to England, provided they skirted the edge of the Gulf Stream.[106]

Near the end of the eighteenth century a German bibliographer compiled a list of contemporary British and American authors, many of whom had made contributions to scientific knowledge. It is a long list including some three hundred American names whose publications were found in individual volumes but more often in periodicals. The great and the humble are here, and standing together with their contemporaries across the sea they remind us once more of the international character of scientific fellowship.[107] Dr. Benjamin Rush of Philadelphia understood it so when he wrote to that thoughtful friend of America, Richard Price; "In science of every kind men should consider themselves as citizens of the whole world."[108]

103 Royal Society Library mss., G.2.6, May 1, 1727; G.2.7, May 10, 1727; D.1, 8, May 10, 1729.

104 *Gentleman's Magazine*, 20: 493–95.

105 Florian Cajori, "The Early Mathematical Sciences in North and South America," p. 133.

106 Royal Library Society mss., L.6.59, May 25, 1732; H. E. Gillingham, *Penn. Mag. of Hist. and Biog.*, Vol. 51; Royal Society Library mss., Letters and Papers, Decade VIII, 189.

107 J. D. Reuss, "Alphabetical Register of all the authors actively living in Great Britain, Ireland and . . . North America, with a Catalogue of their publications." (Berlin, 1791–1803). Dates of publications 1770–1803.

108 Massachusetts Historical Society, *Proc.*, 2nd ser., Vol. 17, April 22, 1786.

FATS AND OILS IN WARTIME

By T. SWANN HARDING

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WAR with Japan has greatly affected our imports of fats and oils. Not counting petroleum oil and the so-called essential oils used in perfumes, there are more than eighteen hundred fats and oils, of which about thirty form an important factor in our peacetime life and are grim necessities in war.

Ordinarily we tend to think of fats as foods—lard, butter, oleomargarine, kitchen grease, and so on. We remember that one factor in the German collapse of 1918 was the low fat content of the civilian diet which deprived the people of valuable energy food and vitamins. To-day the existence of synthetic vitamins renders fats less indispensable in that respect.

But in war or at peace fats and oils are necessary not only for food but also for making soap, paint, varnish, printers' ink, linoleum, metal products, textiles, leather goods and glycerine. Certain oils are also necessary to act as special lubricants for high-speed motors and metal-turning lathes.

In war all these uses become more urgent than during peace. Fats and oils have primary importance as foods because they are of high caloric and energy-giving value. Not only the armed forces but also civilian workers under greater strain and on longer hours need more fats than usual. Fats and oils also carry certain of the important vitamins in solution in many foods and thus assume added importance.

Glycerine is important in the making of nitroglycerine and other explosives. In peacetime it is a byproduct of the soap industry, but in wartime soap becomes a byproduct of the glycerine industry. Incidentally, that is why we should not anticipate a shortage of soap, for we must have large quantities of glycerine both for ourselves and others of the United Nations.

In 1940 about ten billion pounds of fats and oils were used in the United States. Of this amount about six and one half billion pounds went into edible products, two billion were made into soap, another billion went into paints, varnishes, printing inks and linoleum products, while the remaining half billion pounds found a wide variety of industrial uses from making tinplate to use as special lubricants.

Most of these fats and oils were produced in the United States, but about fifteen per cent., or a billion and a half pounds, had to be imported from the Philippines, Africa, Argentina, Brazil, Dutch East Indies and Malaya. We usually produce about all the food fats we need, but we are one third short of producing domestically all the fats and oils we need for soap, we lack more than a third of producing all we need industrially, and half our paint and varnish oils have to be imported.

War in the Pacific has jeopardized two thirds of the fats and oils we usually import. Of course some fats and oils are interchangeable, but a few are all but indispensable. Coconut oil is the ingredient that makes most soaps lather freely. It can be replaced to some extent by palm-kernel oil from Africa or babassu nut oil from Brazil. Hence the composition of certain fats and oil products will have to be changed.

The most extensive cuts will come in our customary imports of a billion pounds of coconut oil, palm oil and tung oil, annually. This will affect the soap

and glycerine, protective coating, tin-plate and textile industries especially. The Department of Agriculture, under its farm-production goals announced January 16, 1942, is seeking to stimulate domestic production to prevent shortages.

During 1941 prices were rising and stocks were being rapidly depleted by increasing demand. In 1941 we used about eleven billion pounds, and in 1942 we shall doubtless use eleven and a half billion pounds of fats and oils, domestically. Add to that from five to eight hundred million pounds to be shipped under the Lend-Lease Program and an additional two hundred million pounds for commercial exports, and you get a total domestic disappearance of twelve and a half billion pounds for 1942.

The original farm-production goals were announced on September 8, 1941, but Pearl Harbor changed all that. Under those goals we should have had a fats and oils deficit of over a billion pounds in 1942, so the new goals called for greater domestic production of fats and oils. Even if these goals are achieved our factory stocks will run only about a billion and a half pounds, which is at least a billion low.

These new goals call for the domestic production of 700 million pounds more oil from peanuts than in 1941, 1,100 million pounds more from soybeans, 600 million pounds more linseed oil from flaxseed, and then, if meat packers adopt new fat-trimming processes that have been suggested to them, we should get an additional 600 million pounds of lard. Butter production just about keeps pace with population increases and we are not in urgent need of any more butter in 1942.

It might be of interest to know what some of these fats and oils are and their principal uses. The following are those used mainly for edible purposes: Butter, lard, tallow, and palm-kernel, coconut, cottonseed, soybean, peanut, oleo, olive and babassu nut oils. The following are principally used in soap-making: Tallow and greases, coconut, palm, palm-kernel, olive and babassu nut oils.

Oils widely used in the paint, varnish, linoleum, oilcloth and printers' ink manufacture are linseed, tung, perilla, castor, soybean and rape oils. Both castor and rape oils are also in demand as special lubricants.

Of these oils we usually imported coconut oil and copra from the Philippines and palm oil from the Dutch East Indies and Malaya. Japan controls the supplies of perilla oil, and tung oil is largely a Chinese product. Alternative sources of supply for coconut oil and copra were the Dutch East Indies and certain other South Pacific Islands, as well as East Africa, from which we may still derive some. We have also obtained considerable palm oil from West Africa in the past.

Some substitutions can also be made. Considerable quantities of babassu and other palm-kernel oils contained in the nuts of tropical palms could be substituted for coconut oil and are actually available in tropical Latin America, but transport, labor and equipment shortages make them inaccessible to us. Brazilian castor and other oils are being imported in part to take the place of tung and perilla oils.

It seems most likely that our remaining supplies of palm and coconut oils will be used altogether in industrial rather than in edible products wherein soybean and peanut oils readily replace them. However, peanut and soybean oils can be used in soaps only with difficulty, due to technical factors, but simple hardening renders them immediately useful in foods. Domestic linseed oil will also take up the slack in drying oils as we increase its production.

Department of Agriculture programs covering increased 1942 production of

peanuts, soybeans and flaxseed for oil involve price support in all cases and loans on flaxseed in addition. Price ceilings were imposed on fats and oils late in 1941, and a 90-day-supply order was issued to prevent hoarding. Early in 1942 the Office of Price Administration raised the ceiling on cash lard prices. These rulings both tend to conserve supplies and to give incentive for additional production.

Even if the soybeans and peanuts for oil required are produced other difficulties must be surmounted. The problem with soybeans is to provide sufficient crushing facilities to process thirty million bushels more than the quantity normally processed in the Midwest. But there are ample crushing facilities in the South and the Southwest. It remains to be decided whether to ship the beans to the crushers or the crushing equipment to the beans, and the latter will probably prove more economical.

There is no processing-equipment problem with peanuts, but they are a little difficult to raise successfully. Furthermore, peanut picking machines are required and they cost about five hundred dollars each, priorities being involved. This is more than the average individual grower can afford to pay, so financial arrangements must be made, perhaps on a community basis, to provide the pickers.

In order to procure more long-staple cotton farmers have been urged to plant their full national acreage allotment of about 27½ million acres in 1942. As much as possible should be put into medium or longer staple varieties. A substantial increase in the production of cotton-seed oil should result from this, an increase of from 150 to 250 million pounds, depending upon the actual increase in the cotton crop itself over that of 1941.

The 1942 farm-production goals also call for slaughter of ten million more hogs in 1942 than in 1941. This increase, along with improved methods of cutting out the fat, should yield us an additional 300 million more pounds of lard. It is estimated, finally, that an additional 700 million pounds of fats and greases could be recovered by more careful conservation methods in homes and factories. A campaign for home grease conservation will soon get under way.

It certainly appears that we should be able easily to make up our fats and oils deficit by increased domestic production. We should even be able to enlarge our rather low permanent stocks. Both because of this and because glycerine is such an important by-product of the soap-making industry, it is ill-advised either to hoard soap or to attempt the kitchen manufacture of our own.

A preliminary survey made by the Department of Agriculture as of March 1 indicated that American farmers were planting a million more acres of soybeans for oil than the goals required, but plantings of peanuts for oil would be 1½ million acres short of the goal. Flax acreage was up 20 per cent. over 1941, but was still half a million acres short of the goal. Farmers were therefore urgently asked to increase their soybean acreage still further beyond their March intentions, because considerable substitution can be made among these vegetable-oil crops. That is the latest word at this writing.

BOOKS ON SCIENCE FOR LAYMEN

THE HARVARD BOOKS ON ASTRONOMY FOR THE LAYMAN[1]

NINE books covering the whole field of astronomy have been projected in this series, and four have already appeared. Since the authors are all members of the staff of the Harvard College Observatory, the little volumes are known as the Harvard Books on Astronomy. There has long been a need for books that would give the layman somewhat more than the extremely popular ones, and yet that were not as technical as the college texts or scientific papers. The Harvard Books occupy this intermediate place. They are up-to-date, and contain much material that has not before appeared in book form. Many new astronomical photographs are included among the abundant illustrations. Edited by Dr. Harlow Shapley, director of the Harvard College Observatory, and his associate, Dr. Bart J. Bok, these books will be welcomed not only by the laymen but also by all amateur astronomers, and they will be indispensable to teachers of astronomy.

EARTH, MOON AND PLANETS

In this little volume, Dr. Whipple tells the story of the planets and our satellite, the Moon. He discusses in non-technical language the physical conditions of the planets and their atmospheres, the possibility of life on other worlds than ours, and the theories for the origin and evolution of the solar system. The Moon is considered with regard to its probable origin, as well as the development of its craters, mountains and other features.

In this book on highly calendered paper are superb photographs of the planets made by E. C. Slipher, of Lowell Observatory, who has made the best planetary photographs ever secured. All the planets are shown—even some of the recent photographs of Mars made in 1939 by Slipher in South Africa. A unique feature of the book is The Planet Finder, which enables one to locate all the naked-eye planets in the sky from the present time to 1970.

BETWEEN THE PLANETS

Dr. Watson discusses all the celestial bodies in our solar system except the nine major planets and their satellites, these having been treated in Dr. Whipple's book. Dr. Watson tells the story of the asteroids or minor planets from the discovery of Ceres in 1801 down to the present time when nearly 1,500 are known. He describes the comets as to structure and orbits, explains how Jupiter captured his family of comets, and how comets disintegrate or waste away as they travel around the Sun.

An outstanding feature of the book is the treatment of meteors, meteorites and meteorite craters. Here we have the latest information regarding meteor showers in relation to disintegrated comets; the recent accurate determination of velocities of meteors and what these indicate as to the origin of meteors and their relation to the solar system. The principal meteorite craters are described, as well as the largest and most striking meteorites known. Instruction is given in the identification of meteorites.

THE STORY OF VARIABLE STARS

This book will be of great interest to the host of variable star observers throughout the world, for here we have a description of the technique of observation as well as an analysis of the present status of our knowledge of variable stars. The senior author is the dean of pro-

[1] *Earth, Moon and Planets.* Fred L. Whipple. Illustrated. vi + 293 pp. $2.50. October, 1941; *Between the Planets.* Fletcher G. Watson. Illustrated. v + 222 pp. $2.50. September, 1941; *The Story of Variable Stars.* Leon Campbell and Luigi Jacchia. Illustrated. v + 226 pp. $2.50. October, 1941; *The Milky Way.* Bart J. and Priscilla F. Bok. Illustrated. v + 204 pp. $2.50. September, 1941. The Blakiston Company.

fessional observers of this class of phenomena, and he has for many years been a leader in organizing, directing and inspiring the amateurs in phases of this work in which they can contribute something of value.

The discovery and development of the great astronomical yardstick, based upon the period-luminosity relation of the Cepheid variable stars, an epoch-making advance in astronomy, is here described in a fascinating manner. Another absorbing story is that of the Novae, the most spectacular stars in the sky.

The Milky Way

This book is a stimulating presentation in semi-popular form of the history and present status of our knowledge of the Milky Way Galaxy. We are taken on an imaginary journey of exploration through this great system of two hundred billion stars. The story is told of the unfolding of our comprehension of this vast lens-shaped aggregation of suns; how its nature and composition were determined; how its dimensions were measured; how it was found that the Sun was not at its center, but between thirty and thirty-five thousand light-years from the center; how it was determined that our Galaxy rotates as a system once in two hundred million years.

Besides the discussion of the myriads of component stars or suns, we have a treatment of the bright nebulae in the Galaxy and why they are bright, the dark nebulae and interstellar gas. And the age of the Milky Way is considered. Included in a pocket inside the back cover are two excellent large photographic charts, one showing the northern Milky Way and the other showing the southern Milky Way. A feature that will please many readers is the inclusion of portraits scattered throughout the book of thirty of the leading astronomers who have added to our knowledge of the Milky Way Galaxy.

Clyde Fisher

RABIES—ITS PREVENTION AND TREATMENT[1]

The mad dog has been one of the symbols of preventive medicine. The effect of the bite of a rabid animal, the slow incubation, the terrible disease in humans and the prevention through the work of Pasteur have been history-making both scientifically and in the public mind. Such an evident carrier as the dog could be better understood and more graphically represented than the mosquito or the louse or the flea.

Over the years certain deviations from the anticipated results in handling wounds and vaccination against rabies have puzzled health officers and laymen. Dr. Webster's book is a review of known experience to discover the gaps in our knowledge and to face them rather than to develop plausible explanations to quiet further inquiry. Like all biological phenomena there are variations in the way living things react upon each other. The virus of rabies has its own personal and family history, and so has the individual carrier and the human patient. Perhaps this is the reason why rabies statistics lie or seem to do so.

Deep bites *vs.* superficial bites, caustic wound treatment *vs.* milder measures, delayed vaccine *vs.* prompt treatment are analyzed statistically without giving a clear-cut picture of just what is to be expected from therapeutic measures. Critical experimental evidence of the efficacy of vaccine treatment is still lacking and offers a fruitful field for further observation. McKendrick's statistics are quoted to the effect that "if a person is bitten by a rabid dog and takes treatment, his chances of contracting rabies are no more than 1 in 77 and usually as low as 1 in 510."

Besides recommending further investigations it is concluded that "persons exposed to rabies should be given vaccine treatment with confidence that then there

[1] *Rabies.* Leslie T. Webster. Illustrated. vii + 168 pp. $1.25. March, 1942. The Macmillan Company.

is small likelihood of development of the disease."

Dr. Webster concludes his short but important book with definite recommendations as to some twelve groups of cases into one of which practically every case in a doctor's hand will fall.

The strongest impression I get from reading this book is that every effort, no matter how annoying it may be to individuals, should be made to eliminate "carrier" animals by killing or through prolonged quarantine or some other appropriate procedure.

RAY LYMAN WILBUR

AS SCIENCE SEES US[1]

PORTRAITS have been drawn of man from various points of view. He has been represented as a god, a devil, a saint, a sinner, a hero, a poltroon. His vices and virtues have been emphasized and exaggerated in a thousand ways. Professor Needham describes his as the loftiest branch on the tree of life. He shows him briefly against the perspective of the myriad kinds of living organisms that inhabit the earth.

The book consists of two major parts: I, Man in His Biological Aspects, and II, Society in Its Biological Aspects, each consisting of ten chapters. In Part I the author is on the ground he has traversed all his life. Its rich and varied materials are at his command. He sees in man the processes and the physical characteristics that are illustrated more simply in countless lower forms. As he says, "We and the animals have been a very long time on this earth together. We have developed together; and in the beginning of our individual lives we still travel for a time the same old embryonic highway; it is the main-traveled road of physical development, our branch of which leads up to the heights where a higher mental life begins. We travel a little farther at the end, and reach thus a field of greater freedom of action that is all our own."

In this first part, Dr. Needham shows why he has long been regarded as one of the greatest teachers in Cornell. He sees both the diversity and the unity of living organisms. In pointing out their interrelations he enriches man, the summit being the organization and functioning of the higher nervous system. He gives a bird's-eye view of the animal kingdom. He devotes a chapter to man's remote ancestry. He follows a discussion of the vertebrate plan with a brief description of the development of the human brain. He leads on to the problem of learning and to nature and nurture in the human species. The whole first part is clear, entertaining, informative and often inspiring. The illustrations by Mr. William D. Sargent are excellent.

In Part II on Society and Its Biological Aspects a more difficult field is entered, if for no other reason than that the analogies with lower forms of life are fewer and not so close. Such difficult subjects are discussed as instincts, reason, the role of instinct in human affairs, war in its biolgical aspects, government in its biological aspects and, finally, religion in its biological aspects. The author has made a valiant attempt to describe these various human activities as consequences of the biological characteristics of man. Naturally, he entered much new and strange territory, the exploration of a great part of which has hardly been begun. It is not to be expected that his discussion will win such general approval as will that of Part I. Yet it is thought-provoking, for it suggests relatively new approaches to the greatest problems of human society. To say that this part of the book has shortcomings is only to repeat what could justly be said about any other discussion of the great questions that are considered. To have attempted so difficult a task requires courage, and to have succeeded so well is praiseworthy.

F. R. MOULTON

[1] *About Ourselves.* James G. Needham. Illustrated. 276 pp. 1941. $3.00. The Jaques Cattell Press.

THE PROGRESS OF SCIENCE

SIR ISAAC NEWTON, 1642–1727

SOME seven miles south of Grantham in Lincolnshire lies the small village of Woolsthorpe. By going a mile or so beyond this tiny town, one may still see the farm which belonged to Newton's parents and may also visit the large stone house—and even the room—in which he was born. The event of his birth, the tercentenary of which is now being celebrated on both sides of the Atlantic, occurred on Christmas Day, 1642. Here in the quiet surroundings of Woolsthorpe the lad spent the first twelve years of his life. At the end of this period, while Oliver Cromwell was still Protector of England and science was just becoming the fashion of the day, the young boy was sent off to the "public" school in Grantham, where he spent the next five years.

Following this experience, came a brief attempt on the part of his mother—the father had died before the son's birth—to make a farmer of him. She and her brother, the Reverend W. Ayscough, a Trinity College man, were however wise enough to see that the interests of the young Newton lay along the line of kites, windmills, water wheels, sun dials—in short, that he was devoted to mechanics and mathematics.

On the 5th of June, 1661, in his nineteenth year, he was admitted to Trinity College, Cambridge; and in 1665 was graduated B.A. Unfortunately, little is known about what subjects Newton pursued during these undergraduate years; even his class standing is unknown. Papers in Newton's handwriting show, however, that it was in this year that the first ideas of a differential calculus occurred to him. In the summer of 1665 the students of Trinity College were "forced from Cambridge by the plague." The same thing happened again in the following summer. Consequently, a long period of enforced leisure was enjoyed at his Woolsthorpe home. On the first of October, 1667, Trinity College elected him to a fellowship; and he again returned to Lincolnshire until the spring of the next year, when he received the Master of Arts degree. It was about this time that Dr. Isaac Barrow, distinguished mathematician and churchman, resigned the Lucasian professorship at Cambridge. To this chair, his pupil, Isaac Newton, now twenty-seven years of age, was promptly elected in 1669. The crowning honor for any young man—that of election to fellowship in the Royal Society of London—came on the 11th of January, 1672.

The key to such a rapid rise is doubtless to be found in the fact that, during two years of leisure at Woolsthorpe, this young mind had not only developed his invention of the calculus, but had also pondered over Kepler's laws and had wondered whether the curved orbit of the moon was not to be explained by the same force which makes a cannon ball take a curved path and an apple fall, from rest, in a straight line. The inverse square law had occured to other minds, as indicated in the "Principia" (Scholium to Prop. IV of Bk. I.); but Newton set about to verify the law by experiment and thus give it validity and acceptance. He knew fairly well the size of the earth; knew also that the distance of the apple from the attracting center was one radius of the earth, while the distance of the moon was sixty times as great. To obtain the ratio of the squares of these distances is a matter of the simplest arithmetic.

To compare the earth's attraction at the distance of the moon with that at the surface of the earth, Newton relied

upon the definition of force which, by universal experience and consent, makes it proportional to the acceleration produced. The problem is then reduced to a comparison of the distance which an apple falls from rest in one second with the distance which the moon falls away from the straight line tangent to its orbit in one second. But the ratio of these two accelerations did not agree as closely as he had hoped with the ratio of the inverse squared distances. Two uncertainties lingered in his mind: one as to the size of the earth; the other as to whether a sphere, such as the earth, attracts as if its entire mass were concentrated at its center. The first of these doubts was removed by the measures of Picard (1672): the second by a theorem of his own, proving, by his method of fluxions, that any solid sphere, in which the density is uniform over each concentric shell, attracts as if its mass were all at the center. The result was that the law of inverse squares was rendered highly probable.

A few years later this law was firmly established when Newton showed, again by use of his calculus, that, given two spheres attracting each other according to the inverse square law, the orbit of either body about their common center

ISAAC NEWTON, 1642–1727
FROM A PAINTING BY J. VANDERBANK IN THE NATIONAL PORTRAIT GALLERY, LONDON.

THE HOUSE IN WHICH NEWTON WAS BORN

NEAR THE VILLAGE OF WOOLSTHORPE IN LINCOLNSHIRE ON CHRISTMAS DAY, 1642.

of gravity must be a conic. The great paper containing this research was presented to the Royal Society on the 28th of April, 1686.

We are still considering the use which Newton made of his leisure at Woolsthorpe during the years 1665–66. Among his purchases during this period, one finds listed in his note book certain prisms, lenses, drills, putty, "glass bubbles," betraying his early interest in light and in the explanation of color. It is also significant that when, in 1669, he entered upon the duties of the Lucasian chair the subject which he chose for his lectures was optics. A memorable paper containing the outcome of these early optical experiments was presented to the Royal Society on the 8th of February, 1672, approximately one month after his election. A few sentences from this paper will illustrate the manner in which he disposes of the hitherto diverse and fantastic notions concerning color.

> Colours are not qualifications of light, derived from Refractions or Reflections of natural Bodies (as is generally believed) but *original and connate properties*. . . . To the same degree of Refrangibility ever belongs the same colour, and to the same colour ever belongs the same degree of Refrangibility. . . . The species of colour and degree of Refrangibility proper to any particular sort of Rays is not mutable by Refraction nor by Reflection from natural bodies nor by any other cause that I could yet observe.

Looking back over the four years that intervened between his graduation from Trinity College and his appointment to a professorship, one observes that the three outstanding achievements of his life were fairly initiated during this quadrennium. These were as follows:

1. The invention of the calculus—an

honor which Newton shares with the German mathematician and philosopher, G. W. Leibniz (1646–1716). Oddly enough the first printed account of the Method of Fluxions, as it was then called, is to be found in Wallis's "Algebra," pp. 390–396, which appeared in 1693: and then only because some of Newton's friends in Holland had informed him that, on the continent, the "Method of Fluxions" was becoming known as "Leibniz's Calculus."

2. The idea that the moon and the planets are held in their respective orbits by an attractive force varying inversely as the square of the distance from the central body. The mathematical proof of this theorem—presented to the Royal Society on 28th April, 1686—became the basis of the "Principia."

NEWTON'S BIRTHPLACE
THE TRIPLE WINDOW ON THE SECOND FLOOR LIGHTS THE ROOM IN WHICH NEWTON WAS BORN.

3. The simple theory of spectral colors, experimentally established in his youth—together with some later discoveries in interference and diffraction. These first came to light in his "Opticks," published in 1704.

From the preceding, it is clear that this young man at the age of thirty had definitely outlined three monumental contributions to human knowledge, had been elected fellow of Trinity College as well as fellow of the Royal Society and was now filling the leading chair of science at Cambridge University. Among the multitudinous activities of his later life, none exceeds in importance the publication of the "Principia—The Mathematical Principles of Natural Philosophy"—in 1687. Here we owe much to the astronomer, Edmund Halley[1] (1656–1742), who, having come to believe in the inverse square law, went to Cambridge especially to visit Newton in August of 1684. Halley put to Newton this question, "What will be the curve described by a planet round the sun on the assumption that the sun's force diminishes as the square of the distance increases?" To this Newton promptly answered, "an ellipse." When asked for his reason, his reply was, "I have computed it." Halley then secured a promise from Newton to send this demonstration to the Royal Society for record. The promise was fulfilled in February of 1685. The paper carried the title "De Motu." Its four theorems and seven problems proved to be identical with some of the most important parts of the "Principia." We owe still more to Halley; because the Royal Society thrust upon him the responsibility of printing this great work, but gave him no funds to meet the expense. However Halley's brain was not only nimble enough to appreciate the difference between thinking that the moon's motion was consistent with the inverse square law and proving that the orbit of the

[1] An account of the life and work of Halley will appear in an early issue of THE SCIENTIFIC MONTHLY.

moon must be a conic, but he was also generous enough to see the "Principia" through the press. The first edition was practically exhausted within four years of its publication; and a second edition did not appear until 1713. First published in Latin, the one language then understood by men of science in all the countries of Europe, the "Principia" became available to many students in England and in America only after 1729, when it was translated into English by Andrew Motte. It is this edition which the late Professor Cajori has revised and enriched with a scholarly fifty-page appendix. The simple elegance of this volume leaves nothing to be desired. On turning its pages one's only regret is that the pioneer who invented the calculus did not have the courage and wisdom to employ it here in his own book.

In the 382 pages of the "Opticks" (third edition, 1721), which first appeared in 1704, Newton thoroughly established the nature of spectral colors, the interference of thin plates, the phenomena of inflexion and the periodicity inherent in every ray of light.

Twice between the appearance of the "Principia" and the "Opticks" Newton represented Cambridge University in Parliament; but it does not appear that he ever took any very active part in the proceedings.

About this same time, early in the reign of William and Mary, Newton received another governmental appointment of considerable importance. The coinage of England had, since the Restoration, fallen into such a bad condition (owing to clipping and other mutilations) that a large percentage of it was refused acceptance in the payment of taxes. So when Charles Montague was appointed Chancellor of the Exchequer he shortly afterward invited Newton to become Warden of the Mint. In this position the author of the "Principia" ably directed the recoinage of the entire

Deutsches Museum.

CHRISTIAN HUYGENS

DUTCH MATHEMATICIAN AND ASTRONOMER, CONTEMPORARY AND FRIEND OF NEWTON.

metallic currency of England. In 1697, he was appointed to a still more important post, that of Master of the Mint. During all this while, he retained his Lucasian professorship at Cambridge; and it was only after occupying it for thirty-two years that he resigned it in December of 1701 and at the same time his fellowship in Trinity College.

English citizens generally consider the presidency of the Royal Society to be the highest honor which any British man of science can receive. It was in November of 1703 that Newton was elected to this post and annually reelected until his death in 1727. Knighthood came to him in April of 1705, when Queen Anne held court in Trinity Lodge at Cambridge.

The professional student will seek the acquaintance of Newton through the "Principia": but the layman will find a shorter and happier route through the reading of Bernard Shaw's recent play, "In Good King Charles's Golden Days." Here, in the first act, this accurate Irish scholar brings on to the stage (set for the

drawing room in Newton's London house) the following persons in addition to Sir Isaac himself: King Charles II; Godfrey Kneller, the portrait-painter; the Duke of York, later James II; George Fox, the Quaker; Nell Gwynn; Barbara Villiers; Mrs. Basham, Newton's housekeeper, and Sally, the housemaid. Far from being a romance, the play is one in which Shaw, with penetrating knowledge and marvelous skill, makes each reader personally acquainted with the historical characters represented by the *dramatis personae*. Space permits of only a brief sample of the conversation.

CHARLES. We must not waste any more of Mr. Newton's time, Mistress Gwynne. He is at work on fluxions.

NELLY. On What?

CHARLES. Fluxions I think you said, Mr. Newton.

NELLY. What are fluxions?

CHARLES. Mr. Newton will tell you. I should be glad to know, myself.

NEWTON. Fluxions, Madam, are the rates of change of continuously varying quantities.

NELLY. I must go home and think about that, Mr. Philosopher.

NEWTON. [*very seriously*] I shall be much indebted to you, Madam, if you will communicate to me the result of your reflections. The truth is, I am not quite satisfied that my method—or perhaps I had better say the notation of my method—is the easiest that can be devised. On that account I have never dared to publish it.

NELLY. You really think I could teach you something, Mr. Newton? What a compliment! Did you hear that, Rowley darling?

NEWTON. In these very simple matters one may learn from any one. And you, Madam, must have very remarkable mental powers. You repeat long parts from memory in the theater. I could not do that.

NELLY. Bless me, so I do, Mr. Newton. You are the first man I ever met who did not think an actress must be an ignorant ninny—except schoolboys, who think she is a goddess. I declare you are the wisest man in England, and the kindest.

CHARLES. And the busiest, Nelly. Come. He has given us as much of his time as we have any right to ask for.

Here must be left the story of the man whose laws of physics are employed in the design of every motor car, every airplane, every Diesel locomotive, every safe railway bridge.

HENRY CREW

DEVELOPMENT OF THE BETATRON

WITH the production of very high energy electron beams in the betatron or induction accelerator should come new applications of electrons to various practical problems as well as to problems of interest to the physicist. Already the betatron's energy has been extended sufficiently for one of the most promising practical applications. This is the therapy of deep malignant tissue by a penetrating electron beam. For this purpose electrons from the betatron must be capable of penetrating to the center of the human body. The ionization in the path of the beam produces the same destructive effect as the ionization from high voltage x-rays, which are now used in deep therapy. The disadvantage of the x-ray method is that the rays penetrate completely through the body and thus produce damage throughout. However, 20 million volt electrons, which the betatron now produces, penetrate at the most ten centimeters of tissue, and, in general, should produce—according to the estimates of Dr. Phillip Morrison—a maximum ionization effect about two or three centimeters from the end of their range; that is, in the case of 20 million volt electrons, seven or eight centimeters beneath the entrance surface of the body. This means that by choosing the proper voltage for the electron beam the maximum ionization and consequently the maximum damage could be localized on the malignant tissue. A 25 or 30 million volt betatron would be the ideal size for this work.

Although a fraction of the electron beam now escapes from the betatron by

FIG. 1. THE OLD AND THE NEW BETATRON
THE AUTHOR WITH THE TWO INDUCTION ACCELERATORS, OR BETATRONS; THE ORIGINAL 2.3 MILLION-VOLT BETATRON IS SHOWN ON THE TABLE IN FRONT OF THE NEW 20 MILLION VOLT BETATRON.

scattering off of the x-ray target, the ideal arrangement will be to withdraw the beam from the accelerator, as positive ion beams are now withdrawn from the cyclotron, so that the rays will be more homogeneous and less divergent. This development is a matter of time.

Perhaps the most important improvement in the induction accelerator which has come in the last year is one of flexibility of output energy. It is now possible to direct the accelerating electrons against the x-ray target at any stage of their acceleration. Electrons leaving a gun or injector when the magnetic field is very small circulate about the doughnut-shaped vacuum tube and are sped up by the increasing flux linkage produced within the orbit by the alternating current magnet. The voltage gain per revolution is the voltage which would be read on a volt-meter connected to one turn of wire at the position of the orbit. The electrons make as many as 200,000 revolutions, while the magnetic field increases from a very small value to its peak value.[1]

The energy of the original betatron, which was designed and built at the University of Illinois, was fixed at 2.3 million volts by the onset of saturation effects in the iron which brought the orbit in to a target. By eliminating the saturable material and electromagnetically expanding the electron orbit with a pulse of flux this betatron's energy be-

[1] D. W. Kerst, *Phys. Rev.*, 60: 47, 1941; D. W. Kerst and R. Serber, *Phys. Rev.*, 60: 53, 1941.

came easily adjustable to any voltage up to three million volts by controlling the time in the cycle at which the surge of flux expanded the orbit. This development was undertaken for application to the 20-million-volt betatron which has been constructed at the General Electric Works during a leave of absence from the university.

A further comparison of the two accelerators, which are shown side by side in the University Power Plant (Fig. 1), will indicate some of the changes. The small accelerator weighs approximately 200 pounds and has an eight-inch diameter pole face. The large model weighs about three and one-half tons and has a nineteen-inch diameter pole face. One million volts per inch of pole face diameter can be obtained.

The frequency at which the small magnet resonated was 600 cycles per second. This gave approximately 20 volts per revolution to the electrons, and the electrons were injected at an optimum of about 1,500 volts. The larger accelerator operates at 180 cycles per second, where the cooling problem can be easily handled by forced air cooling. The electrons gain a peak of 66 volts per revolution, and are injected at 15 to 20 kilovolts for a very brief time. Since the electrons have approximately the velocity of light, they travel 85 miles in the small accelerator and 260 miles in the large accelerator. The presence of residual gas in the vacuum "doughnut" hinders the electrons by scattering them only when the velocity is low.

Theoretically, the x-ray output of an induction accelerator should increase with the frequency at which the magnet operates. For one thing, the "doughnut" is charged with electrons more frequently and also, since the voltage gain per revolution increases with the frequency, the electrons can be injected at a higher voltage and at this higher

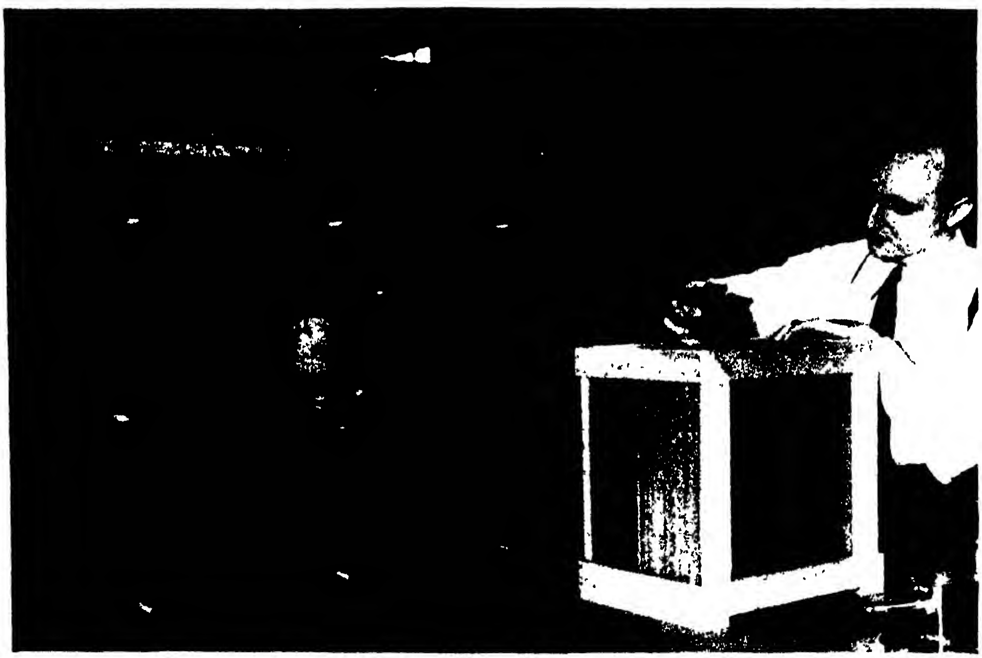

FIG. 2. APPARATUS FOR DETERMINING THE IONIZATION DISTRIBUTION
USED IN THICK SECTIONS OF MATERIAL SIMILAR TO TISSUE.

injection voltage the orbit can hold more electrons against space charge forces. Currents of the order of .01 of a microampere are estimated to strike the target in the small betatron, while the current against the target of the large betatron is about one microampere. However, the rotating electron stream within the large accelerator is probably about 5 amperes. The small betatron required 5 kilowatts of power input while the large betatron takes 25 kilowatts. Recently we have made 60 cycle trials where the power consumption is 3 kilowatts at 20 million volts and the apparatus can be run from the wall outlet.

The fine beam of electrons which circulates in the betatron would be very useful if it could be drawn out of the betatron without much spreading. Such a beam drawn out from a relatively low energy betatron would be useful in an electron microscope where high energy allows thick specimens with small scattering and high resolution. The beam could also be used in other electronic instruments where a compact source of high-speed particles is desirable. Actual tests on the beam size can be made by examining the focal spot on the x-ray target within the induction accelerator. Tests with the small betatron showed that the spot struck by the electrons was less than one millimeter long.

Not only are the primary electrons of possible therapeutic usefulness, but also the very high energy x-rays which can be produced by these electrons may prove useful as a result of the improved distribution of ionization intensity which they will produce within the body (Fig. 2). This distribution of ionization is different from that found with x-rays having an energy an order of magnitude smaller since at 20 million electron volts the secondary electrons which x-rays produce within the body can have ranges comparable with the dimensions of the body. For example, the most energetic Compton electron produced by these x-rays would penetrate 10 centimeters. This large range means that the number of secondary electrons, and hence the amount of ionization reaching a location below but near the surface of the body, is proportional to the amount of tissue which is producing these secondary electrons between the location and the surface of the body. This means that for a certain distance the ionization will increase with depth below the surface. Unfortunately, many of the Compton electrons do not travel straight forward and hence their ionization effect is not carried as deeply into the body as it would be if these electrons, like primary electrons from the betatron, went in one direction. It was in the expectation that the betatron would be developed for general use in these important practical lines and in a compact and convenient form that the details and some of the development of the betatron were taken to an industrial organization.

Among the subjects of interest to the physicist which the betatron opens are the nuclear photo-effect and the study of the interaction of electrons and photons with matter. On the average six to eight million volts are required to remove a neutron from a nucleus of the elements. This neutron can be removed by a photodisintegration process in which a high energy x-ray or photon striking the nucleus ejects the neutron. The residual nucleus will be either a radioactive substance or a stable isotope of the original element. In either case neutrons have been produced. Important things which can be learned are the exact threshold energy at which this photodisintegration of each nucleus sets in, and information about the masses of similar nuclei can be found. The neutrons which are produced in this process will have energies determined by the threshold for photodisintegration and the betatron energy, and thus a

source of neutrons of variable energy is available.

Since the high-energy electrons which have previously been available for experiments come either from cosmic rays, in which case their energy is much higher than 20 million electron volts, or from radioactive substances which give a maximum of 12 million electron volts energy, the betatron furnishes electrons of adjustable energy in a new energy region where the behavior of electrons in penetrating matter, producing radiation and producing positive and negative electron pairs has not been examined. These problems, together with new ones arising in higher energy regions, appeared open to attack by the betatron from the time of the first operation of the small 2.3 million electron volt model. The purpose of our subsequent development was to extend the energy available in our physics laboratory with an induction accelerator following our 100 million electron volt design so that effects in the lower cosmic ray energy range could be studied.

D. W. Kerst

NATIVES OF THE ALEUTIAN ISLANDS

The natives of the desolate, fog-bound Aleutian Islands are not, strictly speaking Eskimos or Indians, although they show unmistakable signs of basic relationship to both these stocks, according to Dr. Hrdlička, anthropologist of the Smithsonian Institution. Only during the past decade has much scientific study been devoted to their origin, and to the history of their bleak habitat before its discovery by Vitus Bering and Chirikov, in 1741.

It now is generally admitted that North America originally was peopled from northeastern Asia by way of Alaska. This was a slow, unorganized migration extending over thousands of years and composed of small groups of physically and culturally diverse peoples of a basic, more or less mongoloid stock, who became the ancestors of the various Indian tribes and the Eskimos. This migration took various routes, one of which may possibly have been by way of the Aleutian Islands, stretching like a chain of stepping stones between the two continents.

Whether or not the Aleutians were an entry route into America, the islands constitute a rich hunting ground for the anthropologist. They are dotted with hundreds of sites of old villages, and the accumulations of these contain a buried record of their former inhabitants, both cultural and skeletal.

Physically the Aleuts stood alone. They belonged to the great yellow-brown racial complex, together with all the peoples of Eastern Asia, the Eskimo and the American Indian. They were among the broadest-headed races on earth. The ratio of the breadth to the length of the head, the so-called "cephalic index," is a hereditary character and one of the most useful tools of anthropologists in determining racial relationships.

Eskimos are a relatively narrow-headed people. The head breadth increases in general from Greenland westward, but even the Alaskan Eskimo has a considerably narrower head than that of the Aleut. Perhaps the nearest approach to the Aleut is found among the "Athabascans" of interior Alaska and Canada, presumably among the latest prewhite migrants to cross from Asia to North America. These northern Athabascans are related linguistically to the Navajo and Apache of the Southwest.

There are various theories to account for the anomalous position of the Aleuts among the American races. The most probable opinion is that they brought their characteristics from Asia.

FAMILY GROUPS OF TYPICAL ALEUTIAN ISLAND NATIVES

Their language, usually divided into two or three dialects spoken respectively in the East, Middle and West of the island chain, is Eskimoid. It has no demonstrable relation to any of the Athabascan dialects, but many words show a close similarity to Eskimo, which itself is not closely related to any other living tongue.

The origin and meaning of the term "Aleut" are disputed. Bering in his reports referred to them only as "Americans." They used to call themselves "Unangans"—probably meaning only "the people." Dr. Hrdlička suggests

HUSBAND AND WIFE
GIRL 12 YEARS OLD AND HER HUSBAND, 60.

A FAMILY OF UMNAK

that the name is composed of Al and Ute, the latter being a general Eskimo term for "people."

At the time of Bering there may have been as many as 20,000 inhabitants on the desolate chain, their numbers being gradually reduced until to-day in the islands they count less than 1,000, and these all mix-bloods.

The government of the Czars at the start of the nineteenth century enacted protective laws for the Aleuts. The apostle to them was a Russian priest named Veniaminov, who must be considered one of the greatest missionaries of American history. He went to the

AN ALEUTIAN COUPLE
SERGEI SUVOROV AND HIS WIFE, AGNES, OF UMNAK.

islands in 1824 and stayed for ten years. A man of much sincerity, zeal and energy, he was very successful, not only in Christianizing but also in civilizing the aborigines.

Almost entirely as a result of his work, the Aleuts became devout Greek Orthodox Christians; they remain so to the present and have not been receptive to missionaries of other creeds. The poorest Aleut to this day dutifully turns over part of his earnings to the church.

By and large, the Aleut has responded well to civilization. He is a man of fair intelligence. The "Aleut" of to-day wears modern clothes, lives in half a dozen little villages of fairly comfortable frame houses; there are few more loyal Americans than these islanders.

Recently the whole small population of the islands has been evacuated by our authorities to prevent them from falling into the hands of the Japanese.

N. M.

SPHAGNUM MOSS FOR USE IN SURGICAL DRESSINGS

In the last world war sphagnum moss was used by the Allied armies on a large scale as a substitute for absorbent cotton in surgical dressings. Its use in that connection was not a new practice; it was merely a revival of a very ancient European performance by country people utilizing mosses and moss peat as sanitary bedding and in the treatment of boils and discharging wounds of man and domestic animals. The material was extensively employed during the last Russian-Japanese war as a first-aid dressing. The Germans, however, demonstrated the value of sphagnum mosses and moss peat in modern, antiseptic methods of surgery. The Canadian Red Cross made over 200,000 moss dressings per month during the summer of 1918, and toward the end of the war the British used nearly a million moss dressings per month.

The American Red Cross officially adopted sphagnum moss as a standard dressing material in 1918 and used it in many American military hospitals. The work of collecting, drying and preparing mosses as pads for surgical dressings was organized in the eastern United States under the leadership of Harry James Smith, of New York, and Dr. Geo. E. Nichols, of Yale University. On the west coast the enterprise was led by Professor J. W. Hotson, of the University of Washington, while in Canada the work was done under the direction of Dr. J. B. Porter, of McGill University.

Advantages of sphagnum moss for surgical dressings. The advantages of a suitable type and quality of sphagnum moss or the peat derived from it, are its high absorption capacity, ranging from 15 to over 30 times the dry weight of the organic material, its sponge-like matting, porosity, softness, elasticity, lightness and strong acid reaction. The secret of the efficiency as an absorbent—taking up liquids much more rapidly and in amounts greater than four times as much as absorbent cotton—lies in the microscopic structure of the leaves of mosses.

Distinguishing characteristics. Not all species of sphagnum mosses or types of moss peat are of equal value for use in surgical dressings. The larger number of the 40 different species in North America is practically of little value for this purpose. Their absorbency is low, ranging from 7 to 10; the plants are comparatively delicate and even with careful handling the leaves and branches break off, are usually brittle when dry and tend to crumble or produce a fine dust. Only the species which form dense foliage and close-set branches exhibit a high capacity for absorbing liquids and possess soft texture and the qualifica-

tions, specified above, of value in surgical dressings. The most promising species, in the order named, are *Sphagnum magellanicum, S. papillosum, S. imbricatum, S. palustre* and to a less extent, *S. fuscum, S. medium* and *S. compactum.* A few of these mosses as well as the peat derived from them are illustrated in Figs. 1 and 2 of the U. S. Department of Agriculture Circular 167, copies of which may be consulted in public and college libraries. *Where found.* Sphagnum mosses are cosmopolitan in their distribution and widely distributed in Eurasia as well as on this continent, including Alaska. They grow best in regions where the climate is moist, where fogs are frequent and summers are cool; they develop luxuriantly near the seacoast, and are more abundant northward than southward. Sphagnum mosses depend upon rainfall for moisture. They are confined to poorly drained areas of peat known as bogs or muskegs, in which trees are usually dwarfed and scattered. The shrubby undergrowth is low and consists predominantly of such heaths as Labrador tea, bog rosemary, laurel, blueberry, cranberry and others. Almost invariably sphagnum mosses constitute a hummocky ground cover with scattered sedges, insectivorous pitcher plant and sundew, and cottongrass. The moss vegetation extends in a well-preserved condition often to a depth of a foot or more below the surface and has either a raised dome-shaped contour or the form of a flat quaking and floating mat. Dry firm bogs which have a more or less tall bushy cover and wooded fringes around the margin of the peat area or swampy forests are least favorable for the growth of mosses.

Information wanted regarding local supplies of sphagnum moss and moss peat. In the last war instructions were issued by Professors Hotson and Nichols in joint agreement with the American Red Cross. Arrangements provided for locating as many good bogs as possible and to explore them; to note their size and accessibility to roads, the purity and amount of moss present, and to collect small samples of surgical moss and moss peat or "peat moss" in selected areas and in different portions of the bog. The material was collected by hand from the surface to a depth of one foot below the surface or to a depth where decay was observed. Each sample was cleaned of twigs and "weeds," gently squeezed to remove surplus water, packed in gunny sacks and labeled with a number and with the name of the locality. In this manner supplies were early located and made up into a monthly output of surgical dressings exceeding 20,000 pads for American war hospitals. Half a million sphagnum moss dressings were prepared for the Italian army.

There is a possibility that during the present emergency surgical dressings again may be required in hospital work in Alaska, Canada and elsewhere on this continent, or for shipment to less favored communities. Hence it seems advisable to anticipate and to prepare for supplying demands for sphagnum moss pads.

A. P. DACHNOWSKI-STOKES

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RECENT ADVANCES IN OUR KNOWLEDGE OF THE PHOTOGRAPHIC PROCESS

By Dr. C. E. KENNETH MEES

DIRECTOR OF THE RESEARCH LABORATORY AND VICE-PRESIDENT, EASTMAN KODAK COMPANY

WHILE many materials are sensitive to light and can be used for making photographs, the present art of photography is based upon one specific process: The light-sensitive material is silver bromide in the form of extremely small crystals held in a layer of gelatin. These crystals are very sensitive to light when the reaction to light is made manifest by the process of development; that is, by the treatment of the exposed material with a solution of a suitable reducing agent. After exposure to light, the crystals are very much more easily reduced to metallic silver than before they have been exposed, and as a result of this difference, the effect of exposure becomes visible as an image composed of metallic silver.

The direction in which advances have been made in recent years is in the elucidation of the structure of the light-sensitive materials and the factors which produce great sensitivity in the silver bromide crystals, so that very small amounts of light are sufficient to make them developable; in the study of the action of light itself and of the change which occurs in the exposed crystals, and in the study of the development reaction by which the exposed crystals are reduced to metallic silver.

The nature of the silver halide crystals and the origin of their sensitivity were elucidated between 1920 and 1930. An adequate theory of the nature of the reaction of light has only become available in the last three or four years, and our views as to the nature of the development reaction have changed very radically in the last year or two.

A photomicrograph of the silver halide crystals of the light-sensitive emulsion is shown in Fig. 1. These silver halide crystals are composed of silver bromide containing a small amount of silver iodide, and they may be dyed to sensitize them to the longer wave-lengths of light. The crystals vary considerably in size but are of the same general shape. They are triangles and hexagons, which are the natural forms of silver bromide, and they are held in photographic gelatin. When they are exposed to light, the silver halide crystals are affected in some way by an extraordinarily small amount of light, as a result of which they become developable.

About twenty years ago, an attack was made on the origin of the sensitivity of the silver bromide crystals by three groups of investigators—Svedberg and his collaborators in Sweden, the British Photographic Research Association in

England and our laboratories in Rochester. Soon after gelatin emulsions were first made, it was found that the exposure required in the camera was greatly lessened if the emulsion had been cooked for some time at a high temperature or if it had been treated with ammonia. It was observed that the grains had grown larger during this treatment, and it was concluded that their greater sensitivity was due to their greater size. This is true, but it is by no means the whole story! For a long time, it had been known that if an emulsion were treated with some chemicals, such as chromic acid, it lost its sensitivity, even though the size of the grains was not changed. Also, sensitivity depends very much upon the particular kind of gelatin used in making the emulsion. Some gelatins easily give very sensitive emulsions, while others, even with prolonged cooking, will not give good sensitivity. This problem has been studied by emulsion makers ever since gelatin emulsions have been made, but no clue was found until Dr. S. E. Sheppard studied systematically the various fractions obtained at each stage in the preparation of photographic gelatin.

Photographic gelatin is made from clippings from the skins of calves. For this purpose, the skin of the face and ears is used because these parts are of no value for leather. These clippings are first washed and then treated with lime for a long time to remove the fat and hair. The lime is removed by long washing with weak acid and then with water. Then the material is cooked in steam kettles until the gelatin is extracted, and the extract is concentrated if necessary and allowed to set to a jelly; the blocks of jelly are cut into thin slices

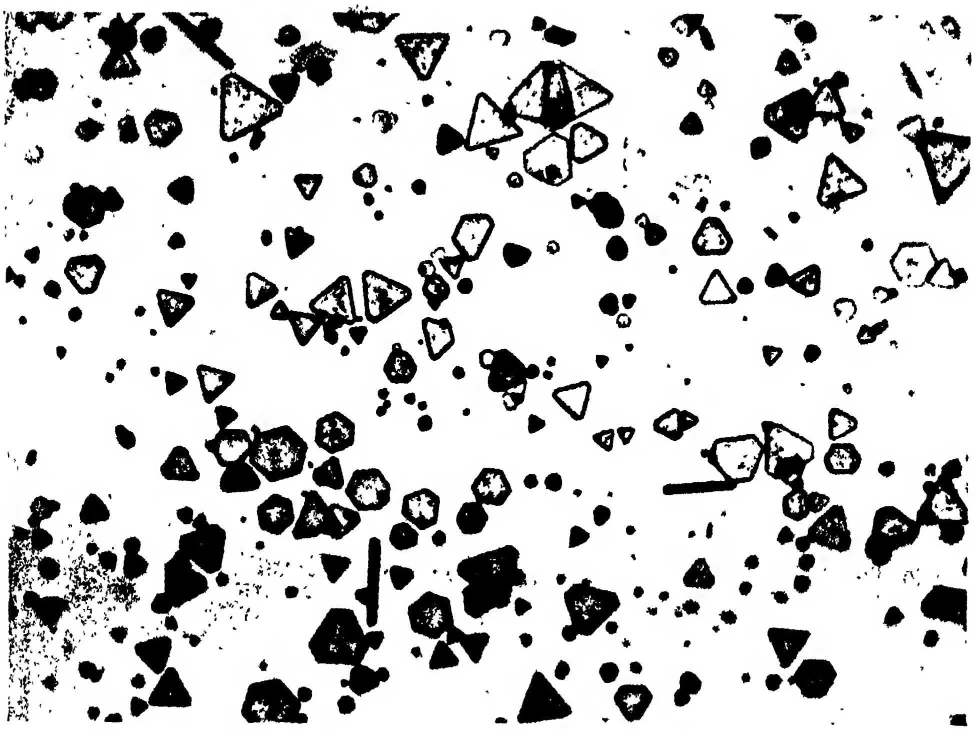

FIG. 1. PHOTOMICROGRAPH OF SILVER HALIDE CRYSTALS. ×2500 OF A NEGATIVE EMULSION. THESE SILVER HALIDE CRYSTALS ARE COMPOSED OF SILVER BROMIDE CONTAINING A SMALL AMOUNT OF SILVER IODIDE.

and stretched out on nets to dry. Sheppard found that in the acid liquors in which the limed clippings had been washed there seemed to be a concentration of some sort of sensitizer. When this liquor was added to a gelatin which did not give sensitivity, it at once increased the sensitivity of the emulsion. From the acid liquor, he extracted a very small quantity of a fatty substance, but when this substance was identified as cholesterol and prepared in a pure state, it had no sensitizing power; the sensitizer was merely associated with it as a slight impurity. However, the fact that sterols can be obtained from the seeds of plants led to examination of extracts of those seeds, and some of them were found to sensitize, the most effective being mustard seed. This led to the identification of the sensitizing substance in gelatin as being mustard oil, which contains sulfur. Presumably, the animals obtain the oil from the plants they eat, so that the amount present depends upon the pasturage they have had.

When mustard oil is treated with alkali, it forms allyl thiocarbamide. If silver bromide is treated with a solution of allyl thiocarbamide, the surface of the silver bromide is attacked and grows a mass of white needles containing both allyl thiocarbamide and silver bromide. When these are treated with alkali, they break down into little black spots which must consist of silver sulfide because of the chemistry of the reaction.

When the development of grains is observed under the microscope, it starts from specks, these increasing in number and size until each grain is transformed into metallic silver. The question arises as to whether these centers of development existed before exposure or came into existence when development started. Sheppard's work put the whole matter beyond doubt. Sensitivity depends upon the existence of specks far too small to be seen in the microscope, and these specks consist of silver sulfide, probably

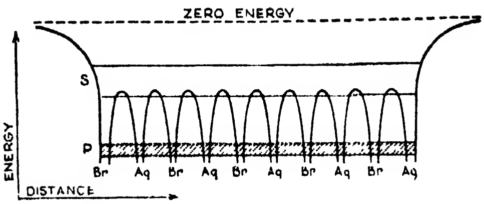

FIG. 2. ENERGY DIAGRAM OF A SILVER BROMIDE CRYSTAL.

derived from the mustard oil in the gelatin. The amount of mustard oil in an emulsion is very small. A ton of emulsion contains only a couple of drops, and the evidence for the existence of the sulfide specks is therefore indirect.

It has already been stated that when a film is exposed to light, an invisible image is produced in the emulsion. To understand how this image is formed, we must know how the sensitizing specks act during exposure and what the light does to the silver bromide.

When Sheppard found that the sensitizing specks consisted of silver sulfide, he and his colleagues advanced a theory of the action of light which they called the "concentration speck theory." The silver sulfide specks, they suggested, are formed on the surface of the silver bromide crystal and must in some way enter into the lattice of atoms of which the crystal is composed. They produce strains in the crystal, therefore, and these strains stretch into the surface of the crystal as an area of weakness. When light falls on such a crystal, energy travels through the crystal until it reaches the boundary of the speck. At this boundary, owing to the sudden change in structure, metallic silver is set free from the silver bromide. The sensitizing speck thus acts as a nucleus for collecting or concentrating the energy throughout the whole area of the crystal and for liberating metallic silver at the speck itself.

There was still wanting a mechanism for the operation of this concentration speck theory. Such a mechanism has

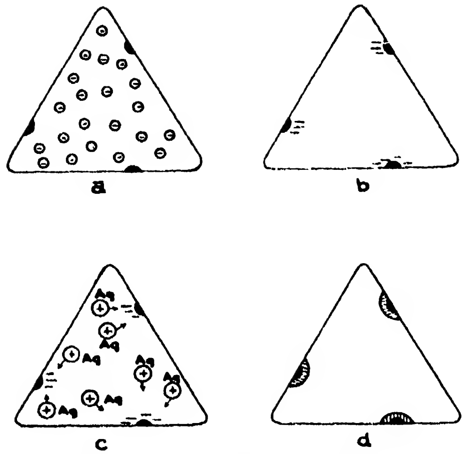

FIG. 3. ACTION OF LIGHT UPON A SILVER BROMIDE CRYSTAL. (A) LIBERATION OF ELECTRONS INTO THE CONDUCTING LEVEL. (B) CHARGING OF THE SENSITIVITY SPECKS BY THE LIBERATED ELECTRONS. (C) MIGRATION OF SILVER IONS TO THE CHARGED SPECKS. (D) DEPOSITION OF SILVER ON THE SPECKS TO FORM THE LATENT IMAGE.

been supplied by the work of Professors Gurney and Mott and of Dr. J. H. Webb. In the first place, if we consider the energy diagram of a silver bromide crystal as a whole (Fig. 2), there are two energy levels of importance in the photographic process, the *S* and *P* levels, in which the electrons may be situated. The *S* band is normally empty and is referred to as a "conduction band." The *P* band is normally completely filled with electrons. Upon exposure of a silver bromide crystal to light which is absorbed in the long wave-length end of the characteristic absorption band, the electrons are transferred from the lower *P* band to the *S* band, and the crystal becomes conducting. This property is well known in other materials, as well as in silver bromide, as "photo-conductance," and the silver bromide crystal exposed to light may be imagined to be filled with a sort of gas of conducting electrons. This is the primary photographic process—the thing that happens instantly when light falls on the crystal (Fig. 3). When the electrons set free in this way reach a sensitivity speck, either consisting of an impurity or of the silver sulfide derived from the gelatin, the electrons will be trapped and the sensitivity speck will become negatively charged by the electrons that it has absorbed.

In a crystal there are always available silver ions in the silver bromide lattice, and these silver ions will travel through the crystal until they reach a sensitivity speck, and there the charge on the ion will be neutralized by the negative charge on a trapped electron and the silver atom freed by the discharge of the ion will be deposited at the sensitivity speck, so that the electrons set free into the conductivity level by the original exposure to light are eventually transformed into silver atoms deposited on a sensitivity speck. This theory postulates that the production of an image by the action of light occurs in two stages: first, the release of free electrons which occurs instantaneously, and then the transfer of the free electrons by neutralization through the silver ions into silver atoms at the sensitivity specks.

This theory of Gurney and Mott supplies a mechanism for the phenomenon known in photography as the "failure of the reciprocity law." Bunsen and Roscoe found that for the photochemical production of hydrochloric acid time and intensity were reciprocal. That is, the production of hydrochloric acid was independent of the rate at which light energy was supplied and was dependent only on the total amount of energy. In the case of photography, however, it is well known that the effect of light is not independent of the rate at which it is supplied. There is an optimum rate for the formation of the maximum amount of photographic image, a rate corresponding to an exposure of a small fraction of a second. If the exposure is much greater than this—an hour, for instance, considerably more energy—two or three times more—may be required to produce the same density of deposit. On the other hand, if the exposure is much

shorter—a ten-thousandth or hundred-thousandth of a second, for example, somewhat more energy will be required. In order to account for the inefficiency of very low intensities of light in producing an image, it must be assumed that the silver atoms formed at the sensitivity specks can easily be lost in the early stages of the formation of the image by acquiring a positive charge owing to thermal action. Thus, for instance, newly liberated silver atoms would be more easily lost than those which have entered a silver crystal lattice to form metallic silver.

On the other hand, with high intensities of light the electrons are supplied too rapidly, the silver ions do not have time to reach the sensitivity specks by diffusion through the crystal, and some of the electrons are repelled from the highly charged sensitivity specks before they can be neutralized. Much light has been thrown on the nature of the reciprocity failure by a study of the formation of the image at different temperatures.

The metallic silver deposited at the sensitivity speck and forming a nucleus which facilitates development is what has been known in photography from the earliest days as the "latent image." There has been much discussion as to the nature of the latent image, but there is now no question that it consists of metallic silver concentrated at local points in the silver bromide crystal. If the silver bromide is exposed to large amounts of light, a visible discoloration takes place, and this undoubtedly consists of metallic silver. This can be shown by the use of the x-rays in the ordinary crystal structure analysis, when characteristic rings of silver crystals are obtained, and also by the examination of the image by means of the electron microscope, when it can be seen to consist of crystals of silver. Inasmuch as the visible image

FIG. 4. ELECTRON MICROGRAPH OF A GRAIN OF DEVELOPED SILVER. ×50,000.

produced by long exposure to light consists certainly of metallic silver, the latent image produced by short exposure is almost certainly of the same nature.

The mechanism of photographic development has always been very obscure. The general theories as to the nature of development until quite recently were those which conceived it as being similar to crystallization from a supersaturated solution of metallic silver. In the absence of nuclei deposition of silver would be delayed, and this would check further solution of the silver bromide. In the presence of a latent image nucleus, deposition of silver is facilitated and the solution, reduction and deposition of the silver bromide continues until the crystal is converted into metallic silver. There are many physico-chemical difficulties in this mechanism, but it would undoubtedly have continued as a possible explanation of development had it not been for the evidence recently supplied by the electron microscope as to the form of the silver produced in development.

The silver grains of the developed image are very small and the microscope is unable to distinguish any appreciable structure in them, so that in spite of some suggestions that the silver might be formed as filaments, the general view was that the developed silver grain was a spongy mass of silver crystals somewhat resembling a lump of coke. When developed silver was examined with the electron microscope, however, it was at once seen that the silver grain is a tangled mass of ribbon-like filaments looking very much like a mass of seaweed (Fig. 4). This is not only very important for the light that it throws on the actual structure of the developed image, but it at once becomes necessary to account for the formation of such an unusual form of silver in the development of the silver bromide. Clearly, the supersaturation theory of development will not do at all. It might be thought that the filaments are formed in cracks in the crystal, but this was disposed of by an examination of the very small crystals of so-called "Lippmann emulsions," crystals too small to be seen in a microscope. With the electron microscope, these appear as normal silver bromide crystals, but when they are developed, each of them turns into a single filament of silver, these filaments being much longer than the diameter of the crystal from which they were formed. The impression therefore becomes overwhelming that the silver filament is formed by ejection from the silver bromide crystal. It is squirted out during the process of development from the solid crystal, and the picture we form of the development reaction is that the reducing ions of the developing agent attack the silver bromide crystal, and in some way the initiation of the formation of metallic silver is facilitated by the presence of the latent image speck.

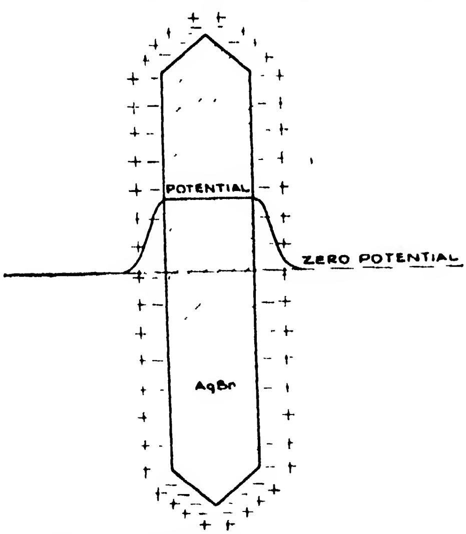

FIG. 5. DISTRIBUTION DIAGRAM OF THE POTENTIAL AND CHARGE OF A SILVER BROMIDE CRYSTAL.

The mechanism for this is supplied if we consider the potential at the surface of the silver bromide. The surface of the silver bromide grain itself has an excess of bromide ions, which give rise to a negatively charged surface. How-

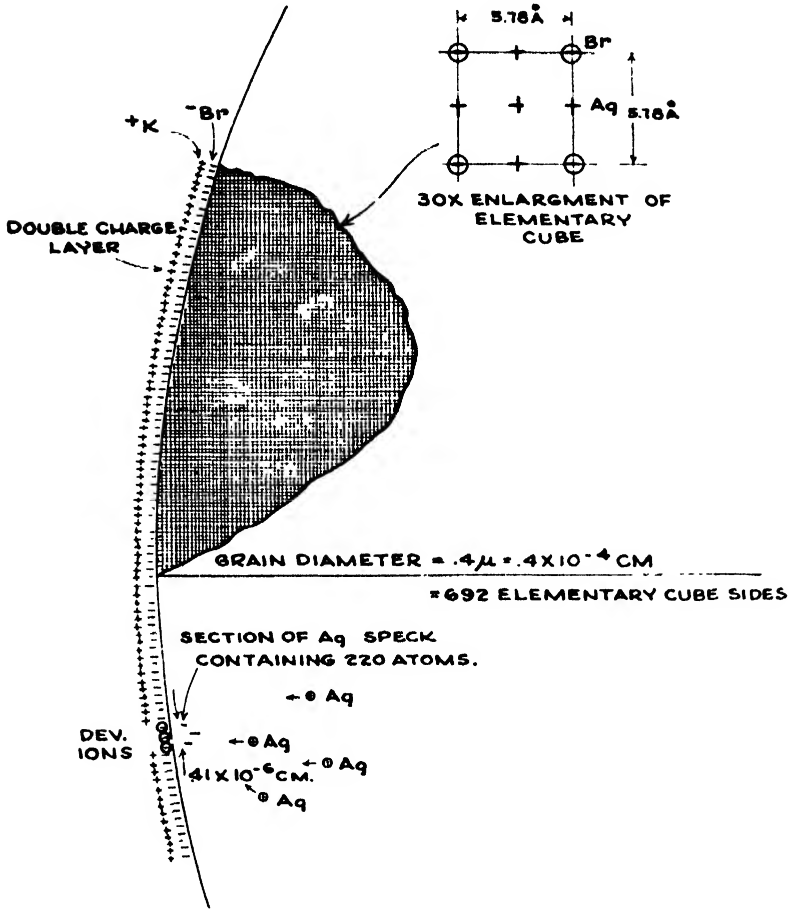

FIG. 6. DIAGRAM SHOWING A LATENT IMAGE SPECK IN A SILVER BROMIDE CRYSTAL ATTACKED BY A DEVELOPER.

ever, just outside this negative charge, a positive layer of potassium ions must be present to neutralize the negative charge. Without such a neutralizing layer of positive ions, it would be impossible for the surface of the silver bromide grain to be covered with negative bromide ions, since the amount of such a charge in so small a region would give rise to explosive forces. A double charge layer, consisting of negative bromine ions on the grain and positive potassium ions in the gelatin just outside, may be considered to exist around the surface of each silver bromide grain (Fig. 5). Grains with such a double layer (in a solution) would move under an electric field as negatively charged bodies, since the negatively charged grain would be forced in one direction by the field, and the surrounding movable positive-ion layer in the opposite direction; but since at any point in the liquid there would be positive ions to form the surrounding positive shell, the double charge layer would be maintained. That the surface charges on the particles and surrounding charge layers do neutralize each other in the manner outlined is proved by the fact that the colloidal suspension does not possess a net charge of either sign but is neutral as a whole.

It may be assumed that a grain, owing to its double charge layer, behaves toward outside charges and also those located inside the grain as a neutral body. An electron placed inside such a double charge layer would experience no force nor, in the same way, would an electron placed outside such a double layer. However, there is a marked difference in potential between the inside and outside of the grain, and the total jump in this potential occurs in the region between the two charge layers. The potential gradient between these charge layers accordingly gives rise to a strong electrical force between the layers, and an electron placed between them would experience a force toward the outside. It is considered that the double charge layer acts in this way as an effective potential barrier to the entrance of an electron into the silver bromide grain of the emulsion and prevents the developer from attacking the grain.

The conditions existing in the exposed grain containing a latent-image silver speck may be seen in Fig. 6. This shows a greatly enlarged scale model of a charged grain surface with a clump of silver atoms on the surface which is supposed to represent the latent image produced by exposure to light. The clump shown includes 220 atoms, with approximately the correct spacing. This size was chosen as representing a fair mean of the values given by various workers.

J. H. Webb assumes that development of a grain is initiated by the break in the double charge layer caused by the silver speck, permitting the negative developer ions to reach this silver speck. The latent-image speck is viewed as an electrode penetrating into the grain. The tendency on the part of the developer ions to release electrons to the silver causes electrons to pass to the electrode and charge it negatively. As explained by Gurney and Mott, this occurs if the electrons of the developer ions are situated in levels above the highest occupied energy levels of the silver metal. The penetration of this negative electrode into the silver bromide grain upsets the neutral electrical condition previously existing in the grain, and there arises an attractive force for the positively charged silver ions in the neighborhood of the latent-image speck. Positive silver ions always exist in the crystal lattice owing to temperature motion, and these diffuse to the speck under the attraction of the negative charge there and enlarge the silver speck. Thus, it is supposed that the original silver speck of the latent image continues to grow by this mechanism. As this proceeds, the protective double layer is more and more ruptured, and a rapidly increasing area of the silver halide grain is exposed to the attack of the developer. Since the reduction of silver bromide by a developer is exothermic, considerable amounts of energy are liberated at the boundary between the silver and the silver bromide, while the local rise in temperature facilitates the migration of silver ions, so that the metallic silver is extruded as a filament.

The process of development itself involves certain requirements as to absorption and catalysis of the development reaction, which explain why one substance is a developer and another reducing agent having approximately the same reduction potential is not a developer. Much work remains to be done on the chemical reactions involved in development, but the knowledge which has recently become available as to the formation and nature of the latent image and its function in promoting the development of the silver halide grain has enabled us to form a much clearer picture of the phenomena of the photographic process than was possible previously.

AGRICULTURAL PRACTICES IN SEMI-ARID NORTH CHINA

By Dr. RAYMOND T. MOYER

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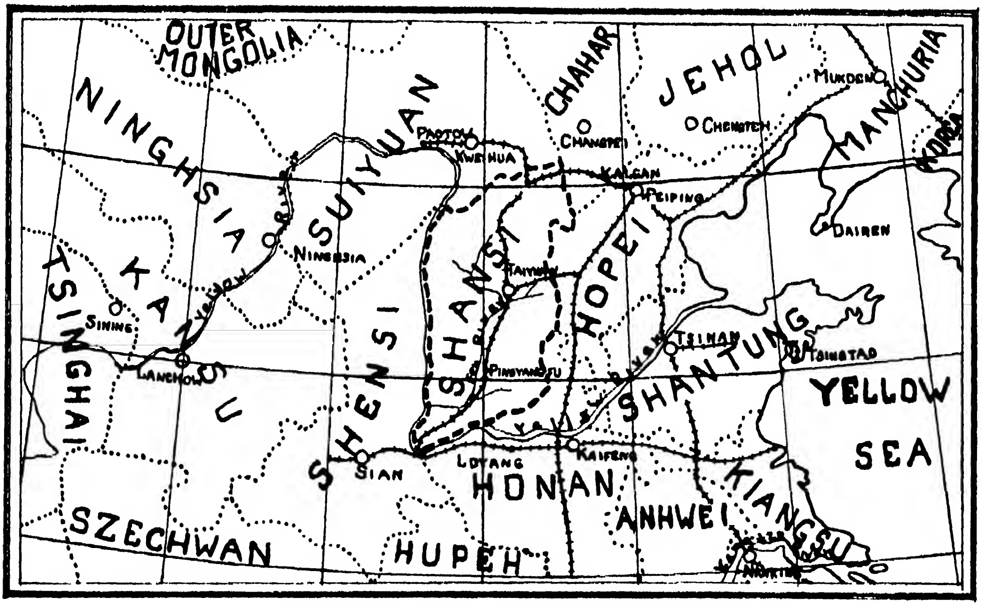
WHILE a good deal has been written concerning agricultural practices in China, most of the existing accounts have had to do with the rice farmers in the canalized regions of the Yangtze delta or with the sturdy plodders on the overcrowded Shantung plain. Much less has been told about farming as it is done in China's semi-arid area, where moisture is the most important limiting factor in production, where one crop per year, not two or three, is the rule, and where the results of erosion stand out so strikingly.

Such are conditions in Shansi, a province just west of the mountains that form an abrupt inland border to the North China plain. Important in Chinese history as one of the first areas to be occupied by the forebears of the present Chinese people, Shansi has latterly received attention because of the immense coal reserves that exist there, and because its mountainous topography and



MAP OF SHANSI AND SURROUNDING AREAS

Between the sub-humid provinces to the east and the arid areas to the far northwest lies Shansi Province, the most typical representative of China's semi-arid region. Shansi is often considered a key to the military control of North China. Other reasons for the current interest in this province are the fact that a considerable amount of cotton is produced on its southwestern plains and that, according to an estimate of the National Geological Survey, it possesses more than half of China's entire coal resources. It has been inhabited since the beginnings of Chinese history; it was the birthplace of the military hero, Kuan Ti, who is now widely worshiped as the God of War; and its business men, during the last dynasty, carried on trade from Kwangtung to Mongolia, eventually to become the nation's largest bankers. To a greater extent even than most provinces in China, agriculture is Shansi's present most important pursuit.

TRAVELER GAZING ON THE GRANDEUR OF THE MOUNTAINS OF SHANSI
Shansi's high altitudes and clear atmosphere remind one of Colorado and Wyoming. Winters at this latitude, which is about that of Richmond, Virginia, are colder than at Cheyenne, Wyoming. However, snowfall is not common, since between 80 and 90 per cent. of the annual precipitation of 16 inches falls during the six months of the growing season.

strategic location make it an important key to the military control of North China. For these reasons it will continue to feature prominently in news from that part of the world.

Lying between the sub-humid provinces to the east and the more nearly arid ones to the west, Shansi represents, better than any other province, the large areas of China's north and northwest which may be designated as semi-arid. The average precipitation of about one third of its total area does not exceed 14 inches per year. In one small section it is as high as 21 inches. The central part of the province, which represents average conditions, receives about 16 inches.

However, with 80 to 90 per cent. of this total precipitation falling within the six months of the growing season, and between 50 and 60 per cent. during the important months of July and August, better crops are often harvested than would normally be expected with so low a total fall. The unfavorable factor in the rainfall situation is an unevenness in the annual supply. Years of a normal fall are interspersed with an occasional year of drought, accompanied by a partial or complete crop failure.

The land surface of this region is about two thirds made up of treeless rock-surfaced mountains, bare of tillable soil except for patches along the sides and in the bottoms of wider valleys. The remaining one third consists of level alluvial plains and of low-lying loess and red soil hills. It is estimated that between 20 and 25 per cent. of the total area is tillable.

With an area of 66,256 square miles and a population estimated, before the war, to be about 12,000,000, Shansi has an average density of about 181 persons per square mile. Kansas, in 1930, had 22.9, Colorado 10.0 and Wyoming 2.3. The size of the farm, therefore, must inevitably be small. Partially irrigated farms have, on the average, between 4 and 6 acres per farm. Dry-land farms on terraced hillsides average between 9 and 15 acres.

The point of particular interest in the agriculture of this region is the accomplishment of its farmers as represented by the successful way with

which they have met the combined problems of so dense a population, a restricted amount of available land and a limited rainfall. With environmental conditions no more favorable than are those of the region occupied by Kansas, Nebraska, Colorado and Wyoming, there has been maintained in Shansi, largely by agriculture, a population which is fourteen-and-a-half times as dense as the average density of the population of these states. In spite of forty centuries of cultivation, soils remain fertile.

Since, under the influence of scientific investigation and social and economic change, the old systems and methods of farming may soon be radically altered, it would seem worthwhile, before this occurs, to record the practices that have helped to make possible these accomplishments of the past.

Considering, first, the soils, it is to be noted that not all are in a state of high fertility. There are alkali spots and areas of unproductive sands. Even on the better soils of the plains there may

THE PEOPLE OF NORTH CHINA

TOP: *left:* A potter using the potter's wheel of ancient standing, still used to make roof tiles. Tiles are first molded on the wheel into a hollow cylinder, which is then cut in two to form half-round tiles ready for the kiln. MIDDLE: *upper:* Little hope remains for these victims of famine. After two years of drought, they are now trying to continue existence on a diet of leaves, roots and weed seeds. So weak have they already become that when the writer accidentally brushed against the younger he fell weakly to the ground. MIDDLE: *lower:* A mountain farmer carrying brushwood, a cheap fuel. However, cutting brushwood robs hills of a cover needed to keep soil in place and to build up the surface of slopes so that a forest might grow there again. *Right:* The owners of the two prize-winning vegetables, leek and kohlrabi, proudly show their exhibits. BOTTOM: *left:* These shepherds, with their sheepskin coats and fur hats, are well-equipped for the cold winter temperatures which often go below zero. *Right:* These farmers are leaving for their orchards with an agricultural extension man who will teach them how to spray properly.

occasionally be seen fields that exhibit symptoms of nutrient deficiencies, particularly the yellowish-green color that accompanies a deficiency of nitrogen. The soils on slopes, where erosion has been active, are definitely low in fertility.

Nevertheless, soils of the plains, where cultivation has been practiced the longest, are on the whole fertile. Yields of wheat, on well-managed irrigated fields, are commonly between 30 and 35 bushels per acre and may reach 60. And the addition of essential nutrient elements, as has been found in numerous experiments, brings about only moderate increases in yield.

This fertility, after so long a period of cultivation, is due to several causes. Soils are deep and of a texture which favors the absorption and retention of moisture. Like the unleached soils of most semi-arid areas, they contain a natural abundance of most of the essen-

TYPICAL SCENES ON THE SHANSI LANDSCAPE

TOP: *left:* A cotton grower takes his crop to market without benefit of modern transportation. After picking, cotton is ginned locally. To transport his crop to the market, this farmer is using a typical birch carrying-pole. By the same method, hundred-pound loads of fruit are frequently taken as far as twenty-five miles in one day. *Right:* Soil eroded from surrounding hills has nearly buried this pear orchard. Many pears are raised on the terraces of this loess basin, but trees are sometimes in danger of being buried by soil washed down from the bordering cliffs and slopes. Farmers prevent this catastrophe by digging away the soil that has accumulated. BOTTOM: *left:* Sheep, when at the home, are kept in small corrals in the courtyard. Since individual flocks of sheep are seldom larger than the one kept by this farmer, sheep owners of a village find it profitable to cooperate in employing a single shepherd, who calls in the morning for his wards and returns them safely at night. *Right:* "Sunken roads," a-much-discussed feature of the landscape, are formed by a process akin to gulleying, when they lie over deep soil materials. Winter winds and summer rains remove particles loosened by passing carts and animals. After many years, this lowers the road until it is often many feet below the surrounding country.

TERRACING AS A MEANS OF EROSION CONTROL
The soil patches on this hillside are very likely the remaining part of what was once a larger area of soil. Although much may already have been lost by erosion, the loss would have been much greater had these terraces not been constructed. The countless number of terraces throughout Northwest China represent an amount of labor almost beyond imagination.

tial nutrient elements. There is, moreover, a more or less regular addition of new material brought about by alluvial and wind deposition. While undoubtedly important, the application of fertilizers is to be considered as only one of the factors responsible for their continuing productiveness.

The attempts of Chinese farmers to increase the amount of land available for tillage have now become largely a matter of history. From the plains, which historical records show were in most cases occupied first, expansion was sought on hillsides. These, it may probably be believed, were at that time partially covered with forests and, in some sites, with soil deep enough to support the growth of cultivated crops.

In such places there must have been obtained, at the beginning, a very fertile soil, rich in humus. But as the humus was gradually lost, the fertility decreased and erosion set in.

The end of the story, which can be read in the conditions of to-day, shows rocky hillsides without either forests, crops or soil. The soil hills, with their deep deposits of loess and red clays, have been badly intersected with gullies, greatly reducing the amount of tillable surface. Heavy rains now run rapidly off the exposed slopes, gather in streams and eventually collect in the major rivers. The river beds, silted up with the eroded material, are unable to accommodate the larger volume of water, and the frequency of floods is increased.

Enthusiastic supporters of an erosion control program in the United States, however, have sometimes overstated the extent to which lowlands have been damaged by rock debris washed down from exposed hillsides. Individual spots have been made desolate in this way. But valley bottoms are, in a large majority of the cases, the most productive spots in mountainous territory.

Nor has the devastation produced by all the forms of erosion combined been

as enormous as statements would sometimes lead one to think. The dense population of this province, supported by agriculture under semi-arid conditions, should alone be convincing evidence to the effect that, in spite of these losses, much good soil still remains even after four thousand years of human

TOWN SCENES ON MARKET DAY

TOP: *left:* This farmer is looking over bolts of material, trying to find cloth he can afford, while the merchant figures up on his abacus what the cost will be. *Right:* Known everywhere as the "big cart," this vehicle is the family carry-all. It hauls manure to the fields, grain to market or the womenfolk to a country fair, all with equal dependability. It is springless, and its wedge-shaped iron-rimmed wheels make rutless roads impossible. MIDDLE: *left:* A showy display of red and blue grapes for sale at wholesale rates in the market. During the height of the season several hundred baskets of this size may be sold in one day to buyers who come from many distant cities and carry back their purchases to sell at retail. *Right:* Before buying for her family, this woman is trying to find the seller who has the best price on the kind of article for which she is looking. BOTTOM: *left:* The size of the bowl of the pipe which this old codger is using could not allow a long smoke. Many men keep such pipes constantly at hand, up an ample sleeve or down the back of their necks, ready for use. *Right:* A farmer buying some rope. Rope has several essential uses on Shansi farms, but for most of the multitudinous uses that American farmers find for it this frugal farmer devises cheaper substitutes.

habitation. In the main, this region is still far from having become a "man-made desert."

A much greater loss could, of course, by now have occurred had not erosion control measures been practiced since long ago. There is hardly a more characteristic feature on Shansi's landscape than the terraced slope. Built up gradually over centuries of time, hundreds of square miles of terraced hillsides now exist, representing an immense effort to prevent the loss of good soil. In the drier less productive parts of this region, proper terraces have not been made. Slight breaks have been formed at intervals along the slope, and temporary ditches are sometimes constructed along the contours to lead off surplus water. Where precipitation is more abundant, and the land more productive, level bench terraces have usually been built. When exposed to unusually severe forces of erosion, stone-supporting walls are frequently added.

The visitor, unfamiliar with such sights, is constantly amazed at seeing small patches of terraced land hanging to a hillside, no doubt the remnant of an area once much larger though still cropped as assiduously as ever.

Such sights, however, are properly to be thought of as more than mere interesting features of the landscape. This laborious preserving and tilling of small isolated pieces of land should be considered as one of the interesting examples of how, through several thousand years of experience, this seasoned race of agriculturists has found a way to cope with the problems with which they have had to deal. Many more examples may be found in the common practices of all branches of their agriculture.

In a sheltered location at the foot of a sunny slope in central Shansi lies a small group of villages around which there flourishes an important grape industry. The vines are trellised overhead, forming a cover over the ground which extends for an area of several square miles. But had nothing been done to prevent a nearby stream from overflowing its banks during the rainy season, much of the fertile land occupied by these vineyards would long ago have been injured by the sand and gravel which would inevitably have been deposited.

To prevent this, protecting dikes have been constructed from time to time along the stream's edge. Just as often, however, deposits from the flowing water have raised the level of its bed, after which the dikes were again raised. And so it has come about that, now, water is carried aqueduct fashion on a bed which is from eight to twelve feet above the general level of the surrounding country.

Equally extraordinary is the way these farmers conserve fertilizing materials with which they are familiar. This is done with an extreme of economy scarcely conceivable to the Westerner. Night soil, which is largely wasted in Western countries, is here carefully preserved and used. Animal droppings on roads are gathered by the feebler members of a household and added to the courtyard compost heap. Animal latrines are placed at intervals along the main highways—spots well bedded with straw or kaoliang stalks where passing animals have learned to stop.

But the climax of their ingenuity is displayed in the mountains, where the scarcity of fertilizers is most felt. Here, an efficient way has been devised to save manure from the thousands of sheep that pasture there during the summer. This is achieved by the simple expedient of having them spend nights on land about to be plowed, at an agreed price. In the morning, the land owner is on hand at daybreak to plow under the added material as soon as the sheep vacate, before a hot sun has had an opportunity to

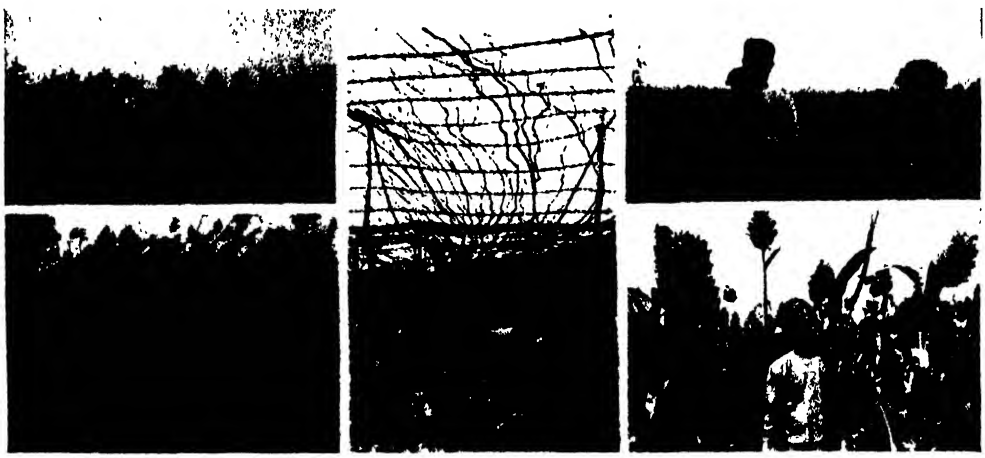
snatch away into the air any part of its valued contents.

Less striking, but of tremendous importance to a successful farming of this region, is the excellent way the crops used are suited to the conditions under which grown. Common soil and climatic adaptations are well understood: wheat and cotton are raised within their ordinary temperature limits; oats and Irish potatoes are main crops in colder regions; and kaoliang, a drought-resistant grain sorghum, is grown under suitable temperature conditions where the rainfall is less, though supplanted with maize where rainfall is more abundant.

But the crop grown nearly everywhere is one which scientific investigations in Colorado have found can produce a greater weight of plant material with a given quantity of water than can any other of the ordinary field crops. This is millet, Shansi's most important single crop.

Not only is millet of value because drought resistant; it is, in addition, extraordinarily useful. The varieties in common use produce more grain than wheat, and the stalks make a suitable fodder for work animals. From one plant, therefore, many peasants obtain their main article of diet; and the need of forage for animal feeding is so completely met by it that practically no land need be devoted to the growing of crops for hay alone.

This fact constitutes an important factor in the ability of this agriculture to provide for the present dense popula-



CROP SCENES OF THE SHANSI AREA

TOP: *left:* Virginia tobacco grows well in Shansi. The increasing popularity of the cigarette has created a heavy demand for improved tobaccos. *Middle:* An important grape growing district has hundreds of acres of vines trellised overhead in this manner. In the late summer the terraces of leafy vines on trellises are banked picturesquely against a hillside and the thickly clustered bunches of grapes hang suspended below. In the fall, the bare vines are taken down and buried in the soil, to protect them against the cold dry winds of winter. TOP: *right:* Millet is Shansi's most valuable crop. The important place given millet has a great deal to do with the ability of this semi-arid region to support so dense a population. It is among the most drought-resistant of crops; it yields more grain than wheat; and its straw provides an acceptable fodder for work animals. BOTTOM: *left:* Like many Shansi farmers, this old man prefers to plant soybeans with the kaoliang, which he is now cutting. BOTTOM: *right:* The English name for this crop, "kaoliang," comes from the Chinese words meaning "tall grain." It is a grain sorghum that is widely used because of its resistance to drought. The grain is sometimes eaten by the peasants, but it is more widely used as feed for animals. Stalks are utilized to make everything from children's toys to courtyard fences.

SHANSI FARMERS HARVESTING THEIR CROPS

TOP: *left:* Aided by scientific methods, these workers are developing new agricultural materials. Improved wheat strains are being developed with methods worked out at Cornell University. Careful tests indicate that, resulting from these efforts, farmers will soon be provided with a new variety which produces between 20 and 30 per cent. more than old varieties when grown under the same conditions. *Right:* An important interlude between periods of work in the field. Work begins at dawn for these farmers. They then return at about eight o'clock for their breakfast. At noon a long interval is taken out for dinner and rest, after which they work until dusk. This rather sensible arrangement allows them to spend a full day in the fields and still to avoid the scorching mid-day sun. MIDDLE: *left:* An ingrained sense of economy requires that peanut land be sifted for stray nuts at harvest time. Sandy soils have been found suitable not only for the growing of peanuts, but also for the hand-sifting to get out all the nuts which they believe to be profitable. *Right:* After kaoliang stalks have been felled, the precious heads are promptly removed and taken home, where there will be less danger of their being stolen. BOTTOM: *left:* Millet gruel alone may be tasteless, but when slices of this pumpkin are cooked with it, the flavor is very much improved. *Right:* A good crop of millet at the threshing-floor. When brought in from the fields, grain is stacked until things are in readiness for threshing. Before threshing, heads are removed from the stalks and spread on the floor for further drying.

tion. Without a crop of such characteristics, there would be insufficient food for so many people. But the extensive use of this crop also illustrates a principle which appears to run through a number of the farming practices. This principle may be stated to be a demand that the resources available for agricultural production shall be utilized in ways so that a maximum amount of food of types suitable for the human population will be produced.

An operation of this principle is likewise to be seen in the manner productive livestock is raised. The forms most commonly kept are sheep, poultry and swine, and the feature in their raising which is of particular note is the way they are fed. In Western countries, the diet of such animals includes large quantities of sound grain which could also serve as direct food for human beings. In China, the feeding of from four to six pounds of grain, to produce one pound of meat, loses, for the human population, too great a part of the total energy values which these substances contain. So livestock is raised principally on materials which have slight or no value for direct human use.

Chickens, accordingly, pick up a large part of their living in fields and village streets or out of grain too poor for sale. Swine are fed on the refuse of kitchens or on otherwise unsalable by-products in the making of certain foodstuffs. Sheep graze the grass of wastelands and receive supplementary feedings of plant remains such as bean stalks and sweet potato vines. It is true that the breeds of livestock which can survive on diets such as these are not models either of form or of productiveness. But they do live and produce. And, done in this way, the inclusion of animal husbandry in their system of farming results in an increase rather than in a decrease of the total amount of food made available for human use.

An examination of the ordinary farm operations reveals, as well, the following of many practices that are of unquestionable soundness.

Soil investigators have, within recent years, found the reason why undecomposed organic matter applied to the soil will sometimes cause young plants to become yellow and stunted in growth. Although the cause of this injury has not been understood by Shansi farmers, they follow a practice which has been found to avoid it. This practice is to compost organic manures. All prosperous households have piles to which are added an assortment of materials collected from the countryside or produced on the farmsteads. As the time approaches to use this manure, the pile is watered and stirred at intervals, until the entire lot is well rotted. The rotted product is then applied to the soil, without danger of injury to the growing crop and with the nutrient elements in a more available form.

The methods used in sowing their crops, likewise, display much skill in dealing with the existing conditions. Since experience has shown that seed placed in a dry soil is usually wasted, planting is not done until sufficient moisture is present in the soil to bring about germination. But on years when the spring rains are delayed or absent, farmers plant not what they most desire, but what they can.

Fortunately, there is available for their choice a large selection of crops and varieties having different lengths of growing period. These include kaoliang, black and yellow soybeans, millet of many varieties, small green soybeans and buckwheat. The proper season for planting each of these crops is thoroughly understood by all farmers, and seed is somehow always secured to meet the various rainfall situations usually encountered. The result is, that unless rains fail completely, no land remains

THE MULE AS AN AID TO THE FARMERS OF SHANSI

TOP: *left:* This newly introduced water wheel, which draws water more quickly than hand labor, is gaining many users. The donkey is blindfolded so that he will follow without question the pull on his bridle exerted by the lead rope. *Right:* A donkey is helping to prepare the winter's supply of millet. The stone roller, which the blindfolded animal is pulling, cracks from the kernel the thin husk in which it grows. The small fanning mill, standing nearby, will later blow out the inedible chaff. MIDDLE: *left:* The old-fashioned plow is not always easy to operate. This implement is handled easily under ordinary conditions, but when ground is hard the plowman often finds his job difficult. *Right:* The sure-footed donkey is a dependable mountain animal. Steep and narrow trails are easily negotiated by this beast, which is commonly used to transport grain from mountain villages to distant market centers on the plain. BOTTOM: *left:* At planting time a locally devised stone packer is indispensable. This ingenious device is a very important factor in the success of Shansi farmers owing to the semi arid conditions, for it prevents the evaporation of moisture. *Right:* Two make a team, regardless of breed. This ox and mule are pulling the common type of harrow. Because farms are usually small, a good team of animals is the exception.

SOLVING IRRIGATION PROBLEMS IN A LAND OF LITTLE RAIN

TOP: *left:* This small stream, a natural source of water, has made this typical loess canyon with its vertical cliffs and curiously shaped pinnacles. Though a stream may flow only during the rainy season, it can quickly cut through deep soil deposits. Because most of the soil materials are calcareous, a protective coating forms on exposed surfaces, and this is in large part responsible for the vertical cliffs and other peculiar shapes that play so important a part in giving loess regions their distinctive appearance. *Right:* Wells provide the source of a good deal of irrigation water on the plains. Frequently the water is drawn by hand from a depth of thirty feet in closely woven willow baskets. This method is very laborious, but irrigated wheat will produce twice as much as unirrigated, which is all the argument these farmers require. MIDDLE: *left:* A bridge serves as a conduit for irrigation water. A small channel provided at the side of this bridge conducts water over a formidable gulley. On the other side it will irrigate small patches of wheat on the fertile soil of a valley bottom. *Right:* When planting time finds the soil depleted of moisture, when possible water is usually run into the rows in which the seeds are planted, or about to be planted. BOTTOM: *left:* Preparing the basins used in a common method of applying irrigation water. The flow of water from wells is usually not large enough to flood a large area at one time; so small basins of this sort are made. These are filled one after the other until the entire field has been covered. *Right:* These farmers are carrying water from the streams below to irrigate newly planted apple trees on the upper terraces. It is a strenuous chore, but all a part of the day's work to mountain fruit growers.

entirely idle. A harvest of some kind, representing the best available under the conditions of that year, is obtained.

Since spring rains are always light, there is frequently present a problem of germination. The seedlings of certain important crops, like kaoliang and millet, have a remarkable ability to hang on during periods of drought, neither growing much nor dying, but then to shoot rapidly upwards when rains finally come. The problem is to get the young plants above the ground.

This difficulty must have taught these farmers, long ago, to pack soil firmly around the newly planted seed. To accomplish this object they have devised an ingenious packer, which must be rated as one of the important factors in their success in farming this dry region. Without it, failures would often result where successes are now obtained.

The essential part of this implement is a set of two or three small, circular stone rollers, which are rounded on the edges to give an appearance like balloon tires. These rotate on axles whose ends are fastened to a simple wooden frame. For nearly all planting on dry land, this packer is pulled by men or an animal through the furrows of the freshly drilled rows. By this method there are eliminated spaces through which desiccating air would circulate, and moist soil is packed close to the seed to start its germination.

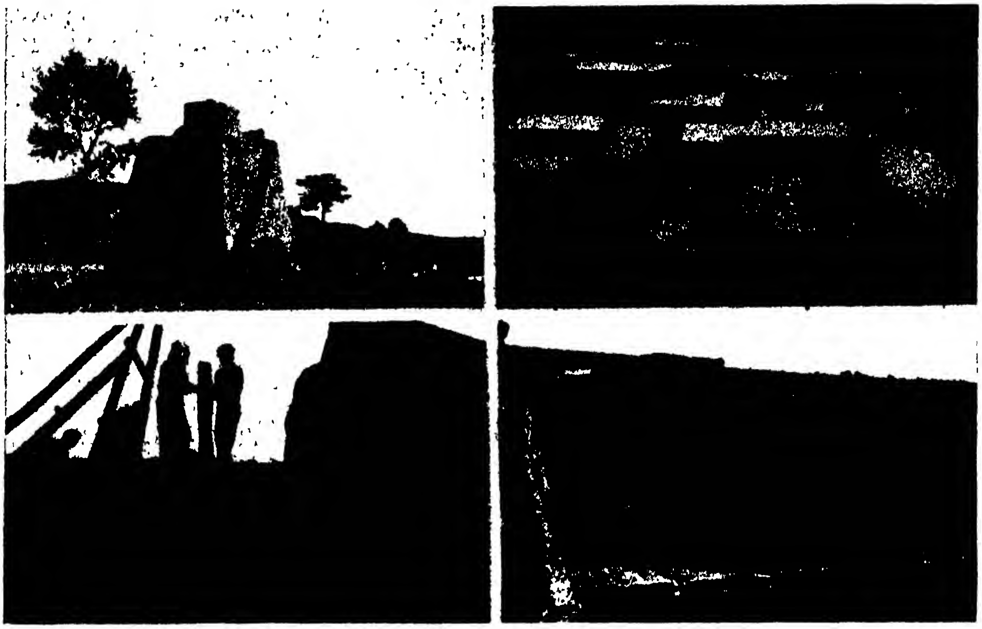
Where possible land is irrigated with water either from streams or from wells. In irrigating wheat during the spring months, it may often be observed that farmers spend long hours laboriously drawing water from wells, not only when the weather is dry but frequently just after a rain has fallen, sometimes even before it has fully stopped raining. The casual observer may consider that, because there has just been a rain, it is unnecessary to irrigate at such times. But the native tells you that an application of water, then, will help insure that the kernels be well filled out later.

In this he is right. Rains at this season of the year seldom penetrate to a greater depth than six or seven inches. From this thin layer of moistened soil the water is soon evaporated by a drying sun and wind.

An irrigation immediately after the rain has fallen forces this moisture downward, to create a reserve which can be drawn upon during the hot dry days that follow.

The same sort of an understanding of how best to manage under existing conditions is seen in certain practices common in sheep raising. The fat-tailed breeds raised in this region are of types which can be bred during the summer months; and farmers see to it that ewes are bred as early in the season as possible. It happens, therefore, that lambing begins in December, about two months earlier than in the United States. For Shansi conditions this is a fortunate circumstance. Because of the scant winter pasturage, sheep are often reduced, by spring, to an emaciated condition. In this state they are not able either to properly nourish unborn young or to provide sufficient milk for the use of offspring following birth. In December and January the ewes are still in comparatively good condition, and lambs, born at this time, are sturdier when born and make a more rapid growth subsequently than when born later.

The difficulty attending this practice is that lambs are born in the severest part of the winter, and special care is required lest the new-born young die of exposure. When flocks are pastured near the owners' homesteads, ewes about to lamb are retained in the courtyard where proper care is given them. But when sheep are on the range, as in Inner



ANCIENT STRUCTURES AND MODERN BUILDING TECHNIQUE
TOP: *left:* Remains of old signal towers are still found along roads which were main routes of the old empire, the relics of a time when express messages were sent by signal fires. *Right:* Nearly all Shansi farmers live in homes built on the courtyard plan. The entrance gate appears at the rear, while at the front on the left is the shed for farm animals. BOTTOM: *left:* Mud is cheaper than brick for a wall to enclose the courtyard. Numerous walls, sometimes even city walls, built by pounding moist earth in molds, may maintain their form and serve for decades, due to the dry climate. *Right:* Double defense gates guard the entrance to the old city of Pingyangfu. The site occupied by this important city in southwest Shansi has been inhabited continuously for several thousand years. Its well-built walls would not be impregnable under conditions of modern warfare, but they were useful even as late as 1936 when Chinese communist troops unsuccessfully sought to force an entrance.

Mongolia, a stable is not always conveniently at hand, and other means of caring for the lambs must be provided.

It was the writer's fortune to be present on one occasion when a lamb was born under such circumstances. Curious to see how the situation would be handled, I watched the procedure. Before the lamb had gotten fully to its feet a shepherd appeared, with a heavy felt bag containing several compartments. Into one of these the lamb was nonchalantly at once slipped, and kept there until eventually it was taken back to shelter. We were informed that, in the large flocks pastured in those regions, as many as twenty to thirty lambs may be born and handled after this fashion in one day.

In practices such as these there is portrayed a great deal of the genius of Chinese agriculture: a prodigious use of human labor, careful attention to the details of farm operation, the employment of methods well-planned to overcome difficulties created by the natural environment, a full utilization of all available resources and a use of these resources in ways which will support the maximum number of human beings.

Yet, in spite of the undoubted excellence of certain practices, there remains a good deal which is short of perfection as judged from the standpoint of mod-

SHEEP AND THEIR RELATION TO AGRICULTURE IN NORTH CHINA

TOP: *left:* The fat-tailed native sheep convert waste crop remains into salable wool and mutton. Livestock in China is expected to live, for the most part, on waste products which the human population can not directly utilize. *Right:* Sheep on mountain pasture provide a boon to mountain crop farmers, who pay cash to have them stabled there because of the fertilizer which they will leave. To the left plows and oxen may be seen standing ready to turn under the additions as soon as the land is vacated, lest a drying sun disperse any of the value into the air. BOTTOM: *left:* A newborn lamb is about to be saved from freezing. Lambs are sometimes born on the open range, away from shelter. To prevent their freezing, shepherds provide heavy felt bags into which lambs are slipped at birth and carried back to the village. *Right:* Rambouillet rams have been imported from Montana to improve native sheep. Preliminary experiments show that crossbred sheep, obtained by crossing this ram with native ewes, produce wool which is worth four times as much per animal as that from present breeds.

ern scientific information. Farmers, generally, do not understand the important practice of seed selection. Fields are not always kept scrupulously free of weeds. And deeper plowing would increase yields from between ten and fifteen per cent., as experimental tests have demonstrated.

At threshing time, bundles of wheat or the severed heads of millet and kaoliang are spread out on a floor of pounded earth. The grain is then beat out with a stone roller, which is pulled round and round while an attendant brings to the surface, with a heavy wooden fork, the unthreshed portion below. This method has the advantage of requiring little outlay for machinery, but it leaves the grain dirty and mixed with grit. Occasionally, caught by an unexpected rain, the grain is seriously damaged. A small threshing machine, owned cooperatively, might be economically feasible and would overcome these difficulties.

Methods of dealing with disease and insect pests are crude and often ineffective. To control a serious pest on the apple and pear, the leaf roller, farmers scrape the bark during the winter and remove infested leaves after the worms have appeared. Their insistence that scraping has value is supported by scientific evidence that eggs of this insect are laid on the bark. But the method as

used is only partially effective and very laborious. Against many other pests—smuts of grain, aphis on cotton and kaoliang, various fruit insects and diseases and parasites of animals—they have little or no defense.

Neither has general use been made, as yet, of improvements that might become available through the use of scientific techniques applied to existing problems. Possible improvements of this sort include better strains of crops and breeds of livestock, new fertilizing materials, more satisfactory methods of disease and insect control and more efficient implements of the simpler kinds. That improvements of this sort may be looked forward to is being demonstrated in the work of experiment stations already established. It is to be expected that, when stable conditions return, rapid progress will be made in incorporating such improvements into general practice.

While war continues, not only is it impossible to make much advance along such lines in the penetrated areas, as in Shansi province, but the rural people who remain there suffer intensely. The course of the war has already seen innumerable villages burned, farm animals appropriated or destroyed, personal possessions lost and the ordinary flow of goods to market disrupted. A severe drought has added to the misery.

Of the future, one thing is certain. The life and farming practices of the rural inhabitants of this region will from now on rapidly change. Social movements, economic developments, political changes and scientific contributions to agriculture will all have a part in altering the life and farming practices which have been. Not for very much longer will this agriculture remain in the unique traditional form into which it has been fashioned by many centuries of a nearly indigenous development.

But few fears need be entertained that the farmers of this region will be incapable of making the necessary adjustments to the new conditions. These sturdy people are unafraid of hard work, eager to live, accustomed to hardship, painstaking in their efforts and ready to adopt new methods when of proven value. When to the heritage received from the experiences of past generations there is made available to them the improvements which investigations scientifically conducted will contribute, there should emerge, on a new level, an agriculture as worthy of respect in the new world as was the old system in the old.

BRITTLE TEMPERATURE OF RUBBER

By M. L. SELKER

CHEMICAL LABORATORIES OF THE BELL TELEPHONE LABORATORIES

INTEREST in the behavior of natural and synthetic rubber at low temperatures has grown considerably in recent years. Airplanes flying at very high altitudes and motor vehicles operating in arctic climates may encounter extremely low temperatures, and since both use rubber compounds, the need for precise knowledge of the behavior of rubber at low temperatures is essential. It has been known that rubber compounds become brittle at very low temperatures, but no published accounts have been found that give the effects of various factors on the brittle temperature for a wide variety of materials. Rubber is used primarily because of its insulating and elastic characteristics, and since the value of rubber insulation is largely lost if the material cracks under shocks at low temperature, the appearance of brittleness seriously affects the insulating power of the rubber as well as its elastic characteristics. The brittle temperature thus determines to a large extent the usefulness of rubber and similar substances at low temperatures.

When crude rubber is held at a moderately low temperature for some days, say in the neighborhood of 14° F, crystallization will occur. The rubber will get stiff and opaque, but will remain elastic to some extent; it can be stretched slightly and be bent without breaking. Well-vulcanized rubber does not crystallize, but as the temperature is lowered, it loses its ability to retract when stretched. If either crude or vulcanized rubber is cooled to some 70 or 80 degrees F below zero, however, it loses its elastic properties completely. If bent suddenly at right angles, it will break off very much like glass. It has been found that this transition to brittleness occurs at a sharply defined temperature, which is different for various natural and synthetic rubbers.

To assist in the study of the brittle temperatures recently made in these laboratories, the simple apparatus shown in Fig. 1 was constructed. A quadrant arranged to carry as many as six rubber specimens is mounted on a shaft, which may be turned with a simple crank, and is supported in a narrow insulated tank into which acetone and dry ice, or other cooling solution, may be placed. The specimen to be tested is fastened to the quadrant and turned down into the cooling solution long enough for it to assume the temperature of the bath, which is determined by suitable thermometers. A quick rotation of the crank then brings the specimen sharply up against a rigid metal bar projecting from the edge of

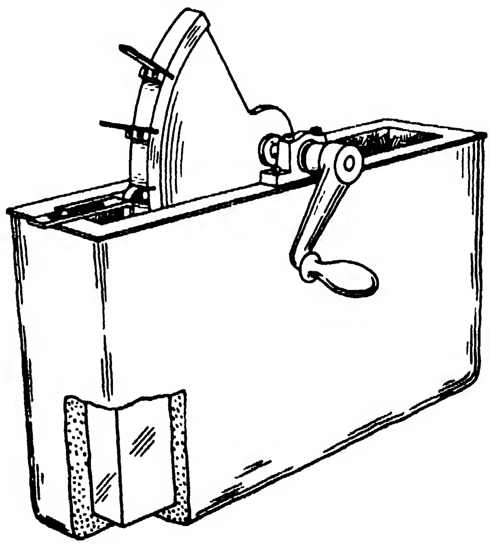


FIG. 1. APPARATUS USED IN MEASURING BRITTLE TEMPERATURES OF RUBBER SPECIMENS.

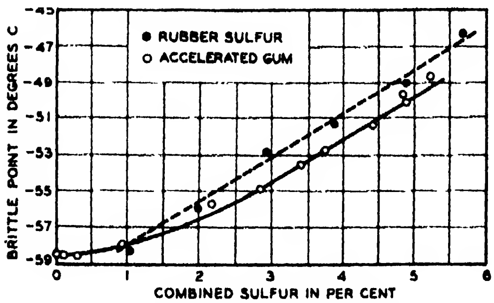


FIG. 2. RELATIONSHIP BETWEEN BRITTLE TEMPERATURE AND PERCENTAGE OF COMBINED SULFUR.

the tank toward the rim of the quadrant. If the brittle temperature has not been reached, the specimen will bend, but if it has, the specimen will break off cleanly. It has been found that the rubber becomes so tough at these low temperatures that considerable force is required to break it, and because of this only a single specimen is usually mounted on the quadrant.

With this apparatus a series of tests were run on a wide variety of natural and synthetic rubbers. It was found that the brittle point of soft vulcanized rubber, which is about −75° F, is essentially the same for all the vulcanizing periods common in industry. Certain of the synthetic mixtures show the same behavior. With rubber compounds vulcanized with an accelerator and a large amount of sulfur, or with sulfur alone, it was found that the brittle temperature varied nearly linearly as the amount of chemically combined sulfur. This is shown in Fig. 2, which gives data for a rubber-sulfur stock and an accelerated stock.

All the usual rubber compounds, the studies indicated, have brittle temperatures above that of crude rubber. Any addition of asphalt or resin, and of many oils, tends to raise the brittle temperature a few degrees. Zinc oxide and carbon black, however, can be added in large quantities with but small effect. The use of appreciable amounts of coarse fillers such as calcium carbonate, on the other hand, produce compounds with high brittle points after vulcanization. The various types of reclaimed rubber can be distinguished on the basis of their brittle temperatures, that from tire-tubes having the lowest. Only two of the synthetic rubbers are comparable to natural rubber in elasticity at low temperatures. Synthetic rubbers also differ from natural rubber in having higher brittle temperatures than their compounds.

There seems to be a relationship between brittle temperature and the size of the molecule of the substance. In general the large molecules have lower brittle temperatures than the small, but the change seems to be sudden rather than gradual, as is indicated by the data in the accompanying table. There seems to be a definite molecular size that must

APPARATUS AND OPERATOR

TABLE I

VARIATION OF BRITTLE TEMPERATURE WITH MOLECULAR WEIGHT

Material	Approx. molecular weight	Appearance	Temperature °C	Temperature °F
Rubber	6,000	viscous brown liquid—solid	−48	−54
"	30,000	masticated pale crepe—soft, tacky	−61.5	−79
"	100,000	pale crepe—elastic solid	−61.5	−79
Polyisobutylene	1,500	viscous liquid	−23	−10
"	10,000	very viscous liquid	−50.2	−58
"	100,000	elastic solid	−50.2	−58
Polyethylene	low	soft, waxy	−15	+5
"	high	tough, waxy but hard	−68.5	−91

be attained before the brittle temperature characteristic of the material is reached. For rubber, this size corresponds to a molecular weight between 6,000 and 30,000, while for polyisobutylene it is between 1,500 and 10,000. The difference between the brittle temperatures for large and small molecules may be very great, as exemplified by polyethylene, which has a brittle temperature of +5° F for small molecules, and −91° F for the large.

COAL HYDROGENATION

IT has been interesting to learn that substantial appropriations have been made for further experiments in coal hydrogenation in the U. S. Bureau of Mines and to read the appeals of experienced engineers. They urge that we begin now to acquire technical information on how best to handle American coals for the production of motor fuels, if for no other reason than to conserve petroleum for high octane fuels and the superior lubricating oils demanded by the modern Diesel and other types of engines.

Nothing quite equals the completion of such work well in advance of the time when it may be needed. The likelihood of early exhaustion of petroleum resources is no greater than it seemed to be a decade ago, but so far as we know petroleum is not being replaced by nature and it is being used at an enormously increased rate by all the nations that can lay their hands upon it. It is none too early to undertake very seriously the type of research and development that would lead to the proper use of coals for the manufacture of synthetic liquid fuels and particularly to provide the lubricating oils not duplicated elsewhere, not to mention the types of fuels which modern motive power utilizes to the best advantage. This does not necessarily mean beginning preparations for the third world war. It simply means taking precautions while we can to get the most out of our raw materials and to guard against the repetition of any of those wasteful procedures that have been so costly in the past. Let us learn all we can while we may. We should learn from present experiences the importance of time, particularly when there are differences in technique, opinion and policy.—*From an editorial, "Industrial and Engineering Chemistry," August, 1942.*

BACTERIA OF THE MARINE WORLD[1]

By Dr. CLAUDE E. ZOBELL

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ALTHOUGH the ocean has been described by bacteriologists as the "world's largest and most efficient septic tank," there are some land-locked biologists who question the existence of bacteria and allied microorganisms in the sea beyond the littoral zones influenced by terrigenous contamination. Certain text-books published during the last decade state that it is virtually impossible for bacteria to thrive in the open ocean, due to a multiplicity of adverse environmental conditions. Purportedly these include the high salinity of sea water, the paucity of organic matter, the processes of sedimentation, the abundance of natural enemies, the germicidal effect of ultraviolet radiations near the surface and the high hydrostatic pressure and low temperature at greater depths.

Believing that high hydrostatic pressures are inimical to life, the author of a recent text-book on general physiology concludes that bacterial putrefaction does not occur at great depths, a deduction which is contradicted by the recovery of viable bacteria from great depths and by evidence of bacterial activity on the sea floor.

Most of the early surveys indicated that while bacteria could be demonstrated in sea water from certain localized regions near land, for the most part bacteria should be regarded as ephemeral transients from a more favorable terrestrial environment. More recent surveys[1a, 2] which have been made in this country and abroad show that bacteria are quite widely distributed in the sea and that they probably play an important role influencing chemical, geological and biological conditions.[3] Specialized analytical methods have revealed the presence of active bacteria wherever water or mud samples have been collected; in mid-ocean more than a thousand miles from land, in water at depths exceeding three miles and buried in fifteen feet or more of bottom sediments.

BACTERIA IN SEA WATER

Bacterial populations ranging from a few hundred to several thousand per cc of water are not uncommon, although there are extensive oceanic zones where there are fewer than one bacterium per cc. The distribution of bacteria is influenced by several interrelated factors of which the concentration of utilizable organic matter is the most important. Usually there are more bacteria along the littoral zones than farther at sea.

Neither latitude nor water temperature directly influence the distribution of bacteria in the sea because extensive populations have been found in Arctic and Antarctic as well as in tropical regions. Wherever other organisms have been found (either plant or animal), careful studies reveal the presence of bacteria and allied microorganisms. Indeed, bacteria have been demonstrated in many marine environments where there is no evidence of other organisms existing.

Water samples from different depths of the sea have been obtained for investigating the vertical distribution of bac-

[1] Contributions from the Scripps Institution of Oceanography, New series, No. 169.

[1a] S. A. Waksman, SCIENTIFIC MONTHLY, 38: 35–49, 1934.

[2] W. Benecke, Abderhalden's Handb. der biol. Arbeitsmethoden, Abt. 404, Lfg. 404: 717–872, 1933.

[3] S. A. Waksman, *Ecol. Monogr.*, 4: 523–529, 1934.

teria by means of a pressure-resistant collapsible rubber bottle stoppered with a hermetically sealed capillary glass tube. The apparatus can be sterilized by boiling or autoclaving and lowered into the sea clamped to a hydrographic wire or cable. When the desired depth is reached a messenger (a weight which slides down the cable) is dropped. The messenger strikes a lever which breaks the glass tube two or three inches from any source of extraneous contamination, thus permitting the sterilized bottle to fill with sea water.

Living bacteria have been recovered from a depth of 5,000 meters where the hydrostatic pressure is around 500 atmospheres, or 7,500 pounds per square inch. Although it is not known how many bacteria may be killed by being hauled rapidly to the surface from great depths, experiments indicate that most bacteria tolerate such changes in hydrostatic pressure.

Bacteria, like nearly all other forms of marine life, are more abundant in the topmost 100 meters of water than in any zone at greater depths. This is attributed to the greater abundance of food in the upper zone which is derived directly or indirectly from photosynthetic organisms. The vertical distribution of the latter is limited primarily by the depth to which sunlight penetrates. Water temperature and the concentration of plant nutrients are also important factors.

The concentration of plant nutrients is influenced by the vertical movement of water masses[4] as well as by the mineralizing activities of bacteria. Water from the photosynthetic zone at stations

[4] H. U. Sverdrup, *et al.*, "The Oceans: Their Physics, Chemistry and General Biology," 990 pp. New York: Prentice-Hall, Inc. 1942.

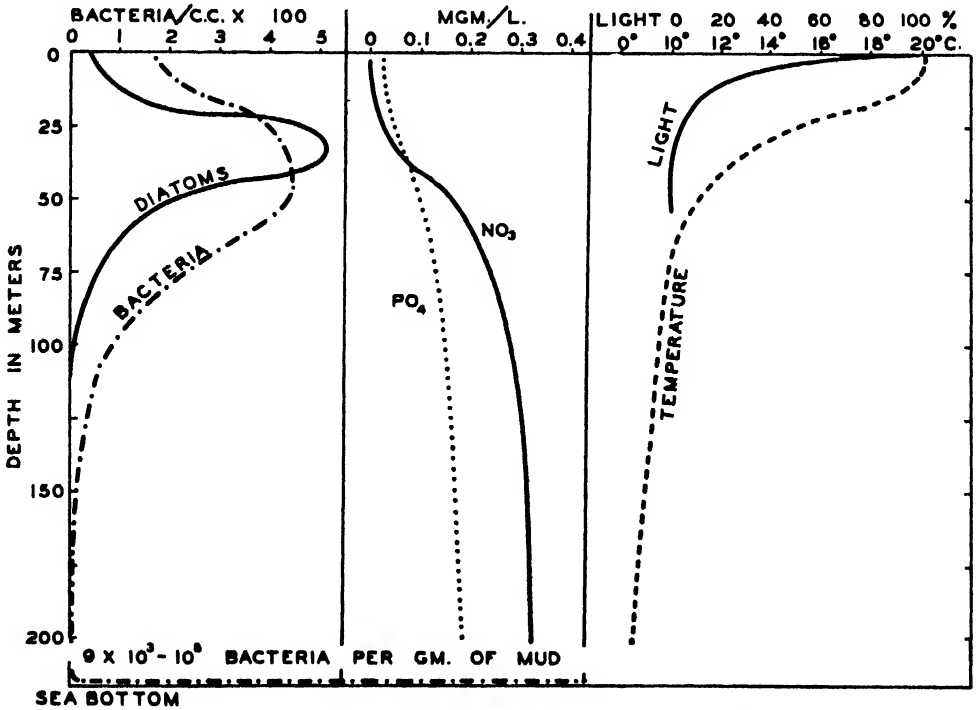


FIG. 1. VERTICAL DISTRIBUTION OF BACTERIA

(NUMBER PER CC OF WATER), DIATOMS (NUMBER PER LITER OF WATER), PHOSPHATE, NITRATE, LIGHT AND TEMPERATURE IN THE SEA BASED UPON THE AVERAGE RESULTS AT SEVERAL DIFFERENT STATIONS OFF THE COAST OF SOUTHERN CALIFORNIA

remote from land generally contains from a few to a few hundred bacteria per cc. Occasionally several thousand bacteria per cc of water are found in certain localized areas.

At all latitudes where observations have been made the number of bacteria decreases rapidly with depth. This is illustrated by Fig. 1, which also shows the vertical distribution of phytoplankton, nitrate, phosphate, temperature and light. One rarely finds more than one to ten bacteria per cc below 200 meters except on the sea bottom.

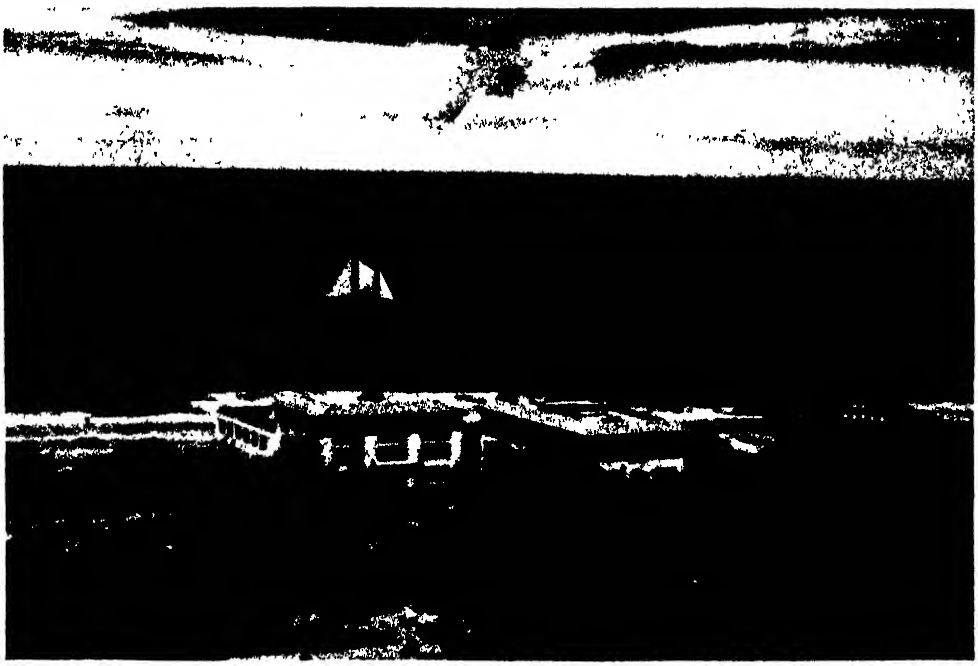
The analysis of water samples collected daily from the end of the S.I.O. pier for a period of ten years reveals that the seasonal distribution of bacteria tends to follow that of phytoplankton. As a rule the largest bacterial populations occur from January to March and the smallest from May to July. However, localized conditions often cause marked fluctuations from day to day.

Bacteria in Marine Mud

The richest microflora is found on the bottom of the sea.[5] In spite of the fact that the temperature may be from $-0.5°$ to $+2.5°$ C. and the hydrostatic pressure may amount to several hundred atmospheres, or a few tons per square inch, there are often as many bacteria in marine bottom deposits as in fertile garden soil. The topmost layer of mud which is in contact with the overlying water usually contains several million viable bacteria per gram. The number is not a function of the latitude or of the depth of the overlying water, but it is related to the particle size of the sediment and the organic matter content. These properties of the bottom sediment are influenced by oceanic circulation, bottom topography, distance from land and several other other interrelated factors.[4]

The vertical distribution of bacteria

[5] C. E. ZoBell, *Jour. Sed. Petrol.*, 8: 10–18, 1938.



THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

THE *E. W. Scripps*, WITH THREE SAILS UNFURLED, IS SHOWN APPROACHING THE END OF THE PIER WHICH EXTENDS 1,000 FEET OUT INTO THE SEA.

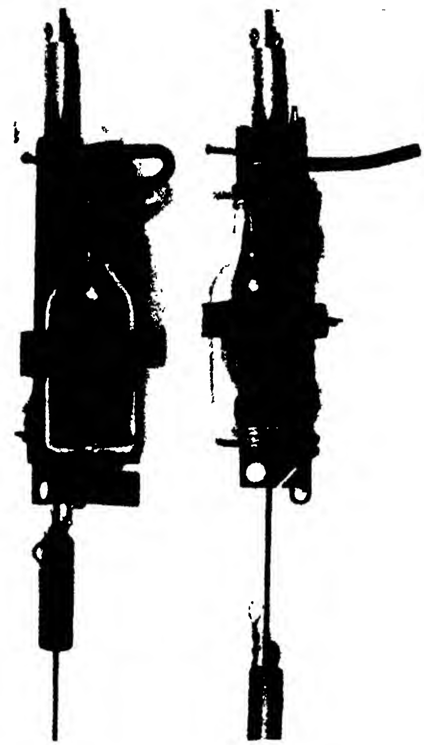
in the bottom deposits has been studied by analyzing long cylindrical cores of mud. The mud cores are collected in a celluloid-lined pipe. The pipe loaded with several hundred pounds of stream-lined lead weights is forced into the bottom mud when it is dropped rapidly, held in a vertical position by the dredging cable. The corer is hauled upon the deck of the research vessel by a power winch and the celluloid barrel full of mud is removed. Radially central portions of the mud cores representing strata from different depths are dissected out aseptically and bacteriologically analyzed.

In the bottom mud the bacterial population decreases from the surface with depth. The bacteria are unevenly distributed, probably due to their tendency to colonize and due to chemical and physical differences within the mud itself. On the average the number of bacteria decreases more or less exponentially from several million per gram at the mud-water interface to a few thousand per gram at depths exceeding 25 cm. Below this depth the decrease is slow and gradual, hundreds of bacteria per gram having been found in mud cores exceeding 500 cm in length. Table 1 shows the number of bacteria which were found in a long mud core collected from the lower end of the Gulf of California at a station where the water was 2,230 meters deep.

TABLE 1

VERTICAL DISTRIBUTION OF AEROBIC AND ANAEROBIC BACTERIA IN A MUD CORE COLLECTED FROM THE GULF OF CALIFORNIA WHERE THE WATER WAS 2,230 METERS DEEP.

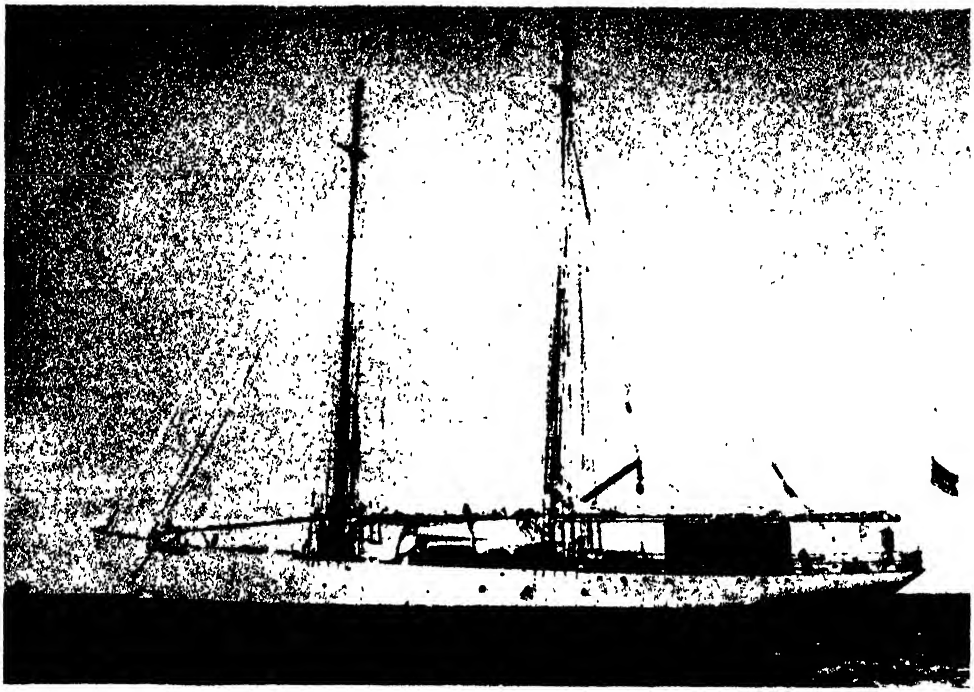
Core depth in cm.	Aerobes per gram	Anaerobes per gram
0– 10	62,000,000	8,900,000
10– 20	470,000	106,000
20– 30	235,000	73,000
40– 50	91,000	23,800
90–100	4,800	2,610
140–150	7,700	1,520
190–200	12,900	870
240–250	2,060	920
340–350	760	218
400–410	164	193
440–450	310	44
500–510	580	26



J-Z WATER SAMPLER

FOR BACTERIOLOGICAL WORK. THE WATER BOTTLE ON THE LEFT IS IN A POSITION TO COLLECT A SAMPLE OF SEA WATER. THE UPPER MESSENGER IS ABOUT TO STRIKE THE LEVER WHICH BREAKS THE CAPILLARY GLASS TUBE AT THE POINT INDICATED. WHEN THE TUBE BREAKS, THE PRESSURE RUBBER TUBING STRAIGHTENS OUT TO THE POSITION INDICATED AT THE RIGHT. SIMULTANEOUSLY THE LOWER MESSENGER IS RELEASED TO FALL ALONG THE HYDROGRAPHIC WIRE TO A SECOND WATER BOTTLE BELOW. GLASS BOTTLES AS ILLUSTRATED WITHSTAND HYDROSTATIC PRESSURE TO DEPTHS OF TWO OR THREE HUNDRED METERS; COLLAPSIBLE RUBBER BOTTLES ARE USED AT GREATER DEPTHS.

Aerobes as well as anaerobes occur in the mud. Although most of the bacteria have the faculty of living either in the presence or in the absence of free oxygen, some which appear to be strict aerobes are regularly found at the bottom of long mud cores where there is no free oxygen as manifested by the low oxidation-reduction potential and by the presence of hydrogen sulfide.



THE *E. W. SCRIPPS*
AN AUXILIARY SCHOONER, WITH RIGGING FOR UNFURLING 4,000 SQUARE FEET OF CANVAS, WHICH IS USED FOR STUDYING THE OCEAN.

The significance of the occurrence of strict aerobes in a highly reducing environment is a problem for speculation. Are they passive inhabitants of the anaerobic mud, preserved in a state of suspended animation since they were deposited from the oxygenated water several thousand years earlier, or do they respire and reproduce by a mechanism unknown to the microbiologist? Some of the secrets of life might be learned from the study of these unique marine microorganisms buried at the bottom of the sea.

Bacteria occur in the bottom deposits at depths far below that at which any other type of living organism is found. By consuming the oxygen from the interstitial water and otherwise rendering the environment reducing in character, they create conditions which are incompatible to the existence of other forms of life. The bacteria slowly decompose the organic matter which rains down from above, thereby effecting the chemical composition of the mud as well as altering its physico-chemical properties including the hydrogen-ion concentration and the oxidation-reduction potential.

Characteristics of Marine Bacteria

The bacteria which are isolated from the sea at places remote from possibilities of terrigenous contamination differ from their terrestrial cousins in many respects. Morphologically they are essentially like those which are indigenous to fresh-water or terrestrial environments with only minor points of difference.

Bacilli, or rod-shaped bacteria, constitute around 63 per cent. of the marine microflora, 5 per cent. are cocci or spherical and 32 per cent. are spirilla or helicoidal in shape. They average somewhat less than one micron in diameter. A large proportion of them are actively

motile by means of one or more flagella. Gram-negative forms predominate. Only a small percentage of them form endospores. Under suitable conditions somewhat more than half of the bacteria from the sea are chromogenic, producing yellow, orange, brown, red, purple, blue or sometimes green pigments.

Physiologically, marine bacteria are more distinctive, differing from terrestrial bacteria particularly in their salinity requirements. Most of the bacteria from the sea require sea water for their growth following initial isolation, while the bacteria from soil, sewage and other terrestrial sources grow poorly or not at all in sea water media. As shown by Table 2, only 8 to 17 per cent. of the

TABLE 2

RELATIVE NUMBERS OF BACTERIA IN MARINE AND TERRESTRIAL MATERIALS WHICH GREW IN NUTRIENT MEDIA PREPARED WITH SEA WATER AND OTHER SALT SOLUTIONS.

Sample	Number of samples analyzed	Salt solution used to prepare nutrient media			
		Natural sea water	Tap water	Synthetic sea water	3.0% NaCl
Sea water ..	12	100	8	78	56
Marine mud	12	100	17	73	64
Sewage	8	13	100	34	29
Tap water .	8	3	100	40	31
Soil	8	14	100	52	46

bacteria from sea water or marine mud grow in fresh-water media, while only 3 to 14 per cent. of those in sewage or soil grow in sea-water media. Neither synthetic sea water nor isotonic salt solution is an entirely satisfactory substitute for natural sea water.

Curiously enough, natural sea water is more toxic for fresh-water bacteria than is isotonic synthetic sea water. This is partly due to the presence in sea water of minute concentrations of thermolabile substances probably organic in nature which are bactericidal or bacteriostatic for fresh-water bacteria but do not injure marine forms.

Contrary to popular conception very few marine bacteria are halophilic or salt tolerant. Most of them require around 3 per cent. salt, but very few marine bacteria tolerate salt concentrations exceeding 6 per cent. Paradoxically a larger percentage of terrestrial than marine bacteria can grow in solutions containing from 6 to 10 per cent. salt. Korinek[6] and others[7] report that in general terrestrial or fresh-water bacteria tolerate changes in salinity and osmotic pressure better than marine bacteria.

The specific salt requirement of marine bacteria may account for the failure of early investigators to find appreciable numbers of bacteria in the sea except in bays, estuaries and littoral water laden with land contaminants. Being guided by conventional standard methods for the bacteriological analysis of water, the investigators prepared their media with fresh water or with ordinary salt.

Many present-day workers are investigating the bacterial flora responsible for the spoilage of catches of marine fish using fresh-water media. Upon a basis of such observations, they conclude that fresh-water or terrestrial bacteria are primarily responsible for the decomposition of marine fish. Other investigations indicate that there are many more proteolytic bacteria associated with marine fish which will grow on sea-water media than those which will grow on standard fresh-water media. This observation leads us to believe that if marine bacteria are treated as physiologically distinctive species, very different conclusions concerning the microflora of living and dead marine fish will be reached.

A large percentage of the bacteria found in the sea are actively proteolytic as indicated by their ability to liquefy gelatin or to decompose virtually all types of nitrogenous compounds with the liberation of ammonia. As a rule they

[6] J. Korinek, *Centralbl. f. Bakt.*, II Abt., 66: 500–505, 1926.

[7] C. E. ZoBell, *Jour. Mar. Res.*, 4: 42–75, 1941.

are less actively saccharolytic than fresh-water or terrestrial bacteria in general, although among the hundred or so species of marine bacteria which have been studied are representatives which attack all the simple carbohydrates. Bacteria which digest starch, cellulose, chitin and lignin occur in the sea. Agar liquefiers are noted on nearly every plate inoculated with sea water or marine mud. Photogenic or luminescent bacteria are also common in the sea. Sometimes enough of them develop in sea water stored in the dark to make it glow with cold light.

Temperature Requirements

Since over 80 per cent. of the ocean is perpetually colder than 5° C., it is not surprising to find that many bacteria from such an environment are able to grow at relatively low temperatures. Although food refrigeration is founded on the principle that low temperatures inhibit bacterial activity, many marine bacteria grow well at refrigeration temperatures. Several species have been studied which multiply and are otherwise physiologically active at temperatures ranging from 0° to −11° C. Indeed, most marine bacteria multiply at 0° C. These cold-loving organisms are sometimes very troublesome in the spoilage of refrigerated foods, uncured furs and other products from the sea.

Marine bacteria as a group are much more thermosensitive than are most terrestrial bacteria. The ability of a group of pure cultures of marine bacteria to survive or to multiply at different temperatures is illustrated by the data in Table 3. Very few marine bacteria survive at temperatures which are optimum for the growth of many terrestrial bacteria, 30° to 37° C. Some marine bacteria are actually killed in 10 minutes at 30° C. Only about half of the marine bacteria studied by the author survived at 37° C. for ten minutes. However, as on the land there are a few spore-formers in most samples of marine materials which are not killed by the boiling temperature of water.

TABLE 3

Number of Pure Cultures of Marine Bacteria which Survived at Different Temperatures for Ten Minutes and the Number which Multiplied in Nutrient Media at These Temperatures, 128 Being the Total Number Tested.

Temperature	Survived	Multiplied	Temperature	Survived	Multiplied
− 4° C.	128	103[a]	42° C.	51	8
+ 3° C.	128	128	45° C.	40	2
22° C.	128	128	50° C.	23	0
25° C.	128	112	60° C.	9	0
30° C.	123[b]	89	80° C.	7	0
37° C.	61	18	100° C.	2	0

[a] Evidence of multiplication after three weeks.
[b] Survived stated temperature for ten minutes.

There are very few terrestrial bacteria which can not withstand 50° C. for ten minutes, but the average marine bacterium is so thermosensitive that it might be inactivated by unduly prolonged exposure to the plating temperature of nutrient agar, 42° C. This psychrophilic thermosensitive characteristic of marine bacteria must be taken into consideration in dealing with them or in evaluating their importance in the world below sea level or their relation to man.

Importance of Bacteria in the Sea

Marine bacteria are not merely biological curiosities. In spite of their minute size, they can be characterized as the mighty mites of the deep in view of their far-reaching effects upon conditions in the sea. Although they are so small that individuals must be magnified nearly a thousand diameters before they can be seen, the standing crop of bacteria in the oceans of the world is estimated to be no less than ten million tons. If they multiply only once a day (and the generation time of some is known to be less than an hour), the annual crop of marine bacteria would exceed 3 trillion tons. These are minimum estimates

based upon an average bacterial population of ten bacteria per cc, each weighing an average of 5×10^{-13} gm.

However, it is not by their mass but by "their works that ye shall know them." And, indeed, we are much more interested in their activity than in the organisms as individuals. Experiments which have been designed to simulate conditions in the sea indicate that bacteria influence the composition and concentration of nitrogen, sulfur and phosphorus compounds as well as the organic content of sea water. Bacteria are present which can oxidize or reduce nitrogen and sulfur compounds; they liberate phosphate from phosphorus compounds, and they mineralize waste organic matter to give carbon dioxide and other plant nutrients.

It is due to their efficiency in mineralizing organic matter that the sea has been characterized as "the world's largest and most efficient septic tank." The organic content of the ocean is kept well below ten parts per million in spite of the extensive animal population and terrigenous pollution.

Bacteria are probably more important than any other group of organisms in reducing the oxygen tension of sea water. There are enough respiring bacteria present to utilize from 0.1 to 5.0 cc of oxygen per liter of water per year in different parts of the ocean. In certain localized regions where oxygen is not readily replaced from the atmosphere or by photosynthetic activity, they utilize the last trace of dissolved oxygen often causing extensive "oxygen deserts."

As a source of food bacteria are consumed by many animals both large and small. Not only do protozoa, copepods and other microscopic animals thrive on a bacterial diet; macroscopic animals, including mussels, oysters, tunicates and worms, can live indefinitely on bacteria.[8] Many animals dwelling at or near the bottom where bacteria are abundant probably derive much of their nutrition from the bacteria which they ingest.

Bacteria as Geological Agents

Through their effects on the chemical and physico-chemical conditions in bottom deposits bacteria exert a far-reaching influence on the diagenesis of sedimentary materials. As the principal dynamic agencies which alter the hydrogen-ion concentration they tend to precipitate or dissolve calcium carbonate (limestone), depending upon whether they increase or decrease the hydrogen-ion concentration. Bacteria are present in marine bottom deposits which can do either, the direction and magnitude of the change being largely a matter of organic, sulfate and nitrate content.

Under favorable conditions bacteria play a role in the deposition of bog iron and in the precipitation of manganese compounds. While there are specific bacteria which oxidize iron and manganese, the state of these metals in sedimentary materials is primarily a function of the oxidation-reduction potential. The latter is influenced by bacterial action.

Certain bacteria transform sulfur compounds, often giving rise to sulfides, free sulfur or sulfates. The decrease in the quantity and changes in the nature of organic matter in sedimentary materials in the initial stages of lithification are attributable primarily to the activities of the microflora.

Do Bacteria Produce Petroleum?

It is still indeterminate if bacterial activities play a role in the genesis of petroleum. In fact, the origin of petroleum is still a mystery, although it is the consensus of oil geologists that petroleum is derived from the transformation of organic matter at the bottom of the sea by either biological, chemical or geophysical agents; probably all three.

[8] C. E. ZoBell, *Jour. Mar. Res.*, 1: 312–327, 1938.

Bacteria possess certain unique properties by which they could contribute to the formation of petroleum and they are present in potential source beds of petroleum in significant numbers.

By reducing the oxygen, nitrogen and phosphorus content of organic matter, bacteria convert it into substances which are more petroleum-like. This is illustrated by the data summarized in Table 4. Very low oxidation-reduction potentials created by bacteria in certain environments are theoretically conducive to the formation and accumulation of hydrocarbons. Methane-producing bacteria occur in marine bottom deposits and it has been postulated that methane might be polymerized geophysically with the formation of higher hydrocarbons. It is not improbable that certain complex hydrocarbons are produced directly by bacterial action on marine sapropel.

TABLE 4
PROXIMATE ANALYSIS OF ORGANIC MATTER FROM DIFFERENT PETROLIFEROUS ENVIRONMENTS

Source of organic matter	Carbon	Hydrogen	Oxygen	Nitrogen	Phosphorus
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Marine sapropel ...	49	5	40	3.4	0.8
Recent sediments ..	58	7	34	2.2	0.6
Ancient sediments .	73	9	14	0.9	0.3
Petroleum	85	13	0.5	0.4	0.1

The occurrence of sulfate-reducing bacteria in oil-well brines and in petroliferous marine sediments, together with the accompanying lower sulfate-chloride ratio, suggests a relationship between these bacteria and the formation of petroleum. Bacteria which oxidize various waxes, oils and other hydrocarbons may be instrumental in the destruction of petroleum under certain conditions.

Disease-Producing Bacteria

Although marine bacteria are predominantly beneficial, there are a few which are pathogenic or disease-producing. Very few of the bacteria which inhabit the sea are pathogenic for marine animals, and as far as is known, none of them cause disease in man. Typhoid bacilli, the vibrio which causes Asiatic cholera and certain other human pathogens, may remain alive for a few days after being discharged into the sea, and hence sea water polluted by man is a potential source of danger, but fortunately such bacteria do not live long in the sea.

It is estimated that there are enough coliform bacteria discharged by the sewage effluents along the west coast of the United States each day to give over a hundred for every liter of water in the North Pacific Ocean if they were uniformly distributed. Yet one seldom finds coliform bacteria in the sea, except in bays or in the immediate proximity of sewage effluents, because they are destroyed so rapidly. However, in the latter places, untreated sewage may be very dangerous to bathers or consumers of shell-fish as well as esthetically offensive.

There is evidence that certain marine animals succumb to bacterial infections. However, the conditions of life in the sea are not conducive to the propagation of pathogens, although parasitic animals thrive there. As soon as a pathogen incapacitates his host, the latter almost immediately falls prey to the ever-present predator and the evidence is destroyed. There is no sanctuary in the sea for the ill or the old where only the fittest survive.

Any diseased fish or other animal which can no longer swim quite as fast as his companions is soon captured and probably eaten by a larger fish or other predator. Consequently the pathogen which incapacitates his host is destroyed also, unless the pathogen can attack the predator. Thus, to incapacitate his host, the pathogen is committing suicide.

Nevertheless, there are some marine pathogens which continue to take their toll of both plants and animals inhabiting coastal waters. A few years ago the lobster industry on the West Coast was threatened by a "soft shell" disease which killed large numbers of lobsters and made others unsuitable for human consumption.

In aquaria, experimental tanks and elsewhere in captivity, many marine animals have their resistance weakened to such an extent that they become victims of bacterial infections. Similarly, kelp, eel grass and other marine vegetation sometimes become infected with devastating pathogenic microorganisms when the resistance of the plants is lowered by storms, man's pollution or otherwise. Bacteria have been observed which injure the pneumatocysts or float bladders of kelp causing the kelp to sink to the sea floor, where it dies and rots. In general, though, while marine bacteria have a predilection for living associated with plants or animals as symbionts, commensals or epiphytes, they rarely injure oceanic hosts.

Sessile Habit of Bacteria

Contrary to popular conception, it is doubtful if many marine bacteria are planktonic or free-floating organisms. Most of them seem to occur attached to objects larger than themselves, such as plants or animals, settling particles of sediment, the remains of dead organisms or other particulate material. This peculiarity of marine bacteria has been attributed to the fact that organic matter is concentrated by adsorption upon solid surfaces where the bacteria can feed more efficiently when attached than when the bacteria are swimming or floating about in dilute nutrient sea water.

Some bacteria have a mechanism for attaching themselves to objects, some are stereotactic, others are adsorbed on solid surfaces and still others are able to grow only on bodies where nutrients are concentrated. Bacteria belonging to the latter category are especially abundant in sea water where organic nutrients are dilute.

Bacteria digest most of their food extracellularly or outside of their own bodies. They must render their food soluble by their digestive enzymes before the food can be ingested. Since there is less than 10 milligrams of organic matter per liter of sea water ordinarily, the bacteria have considerable difficulty in such a dilute medium trying to digest and ingest enough food to satisfy their nutrient requirements because it diffuses away from them about as fast as they can digest it. If, however, the bacteria are on a solid surface which will help to concentrate organic matter and to retard the diffusion of the soluble digested food away from them, they are able to thrive. Recent studies indicate that the solid surfaces also facilitate the orientation of the bacterial exoenzymes in the most advantageous position.

Fouling of Submerged Surfaces

This sessile sedentary habit of marine bacteria which causes them to localize on solid surfaces is sometimes inimical to man. Quite indiscriminately the bacteria grow on virtually all types of submerged surfaces, including ships' bottoms, hydroplane pontoons, water conduits and other man-made structures. After a few days' submergence in sea water the exposed surfaces are coated with a thin layer of bacteria along with other film-forming microorganisms.

The thin layer of film is rarely noticed unless one uses a high-powered microscope or other specialized analytical procedures, and by itself it is quite unobtrusive. However, the film attracts a myriad of tiny larval animals which permanently attach themselves to the surfaces. These attached animals, including barnacles, mussels, oysters, hydroids,

bryozoa and other "fouling" organisms, grow with surprising rapidity, and before many months they are clogging water conduits or seriously retarding the movement of vessels through the water.

There is evidence that bacteria influence the fouling of submerged surfaces in several ways: They discolor bright smooth surfaces which might otherwise discourage the attachment of fouling organisms. Bacteria serve as a source of food for the barnacle and his nefarious kin. They often protect the fouling organisms from the specific poisons in paints either mechanically, by adsorbing the poisons or by rendering the poisons inert by the production of hydrogen sulfide or other chemical substances. Under certain conditions they increase the alkalinity of the surface film, thereby favoring the deposition of the calcareous cement by which certain fouling organisms attach themselves. The bacteria produce plant nutrients which favor the growth of sedentary algae.

As much as 12 to 14 per cent. by weight of the fouling cumulation of ships' bottoms may consist of bacteria. We have isolated nearly fifty different kinds of sessile bacteria from such material, and other investigators are adding steadily to the list.

The so-called "fouling" organisms whose attachment is influenced by the primary film-forming microorganisms are most annoying and they necessitate the frequent drydocking of boats and the reconditioning or replacement of water conduits and other submerged marine structures at considerable cost. It is estimated that in times of peace, fouling organisms cost the United States Navy and merchant marine more than a hundred million dollars annually. In times of war the cost of fouling organisms is inestimable, considering how they retard the speed of vessels, increase fuel consumption and finally necessitate taking important vessels out of commission for cleaning in a drydock at a time when they may be urgently needed. The incrimination of bacteria and allied microorganisms as contributory agents dictates that they be taken into consideration in investigations designed to solve the problem.

CONCLUSIONS

Bacteria are widely distributed in ocean water and bottom deposits. Morphologically they resemble terrestrial bacteria, but they exhibit certain physiological characteristics and cultural requirements which are distinctive. Their sensitivity to temperatures exceeding 25° C., their ability to grow at low temperatures and their specific salt requirements are especially noteworthy.

Bacteria influence chemical, physicochemical, geological and biological conditions in the sea in many ways. Their possible relationship to the productivity of the sea, to the spoilage of marine products of commerce, to the genesis of petroleum and to the fouling of submerged surfaces are practical problems which command attention.

Further information on the bacterial population of the marine world will increase our understanding of oceanic phenomena and the marine environment besides contributing to our knowledge of bacteriology. Eventually it may become possible to apply such information to the control or amelioration of some of the harmful activities of bacteria and to take fuller advantage of those which are beneficial.

BIOLOGICAL CONTROL OF RODENTS AND PREDATORS

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INTRODUCTION

CONSIDERABLE success has been attained and much written on biological control of insect pests. The U. S. Bureau of Entomology has spent a large amount of the energy of its very able research staff on experiments with native and introduced insect parasites and predators attacking or likely to attack the major pests of crop and orchard. In the main these have of necessity been sought in other parts of the world or in other localities. Some of the pests which have been controlled by insect parasites or predators are: the citrus mealy bug, the terrapin scale and the cotton cushion scale. Many other pests are reduced in numbers by introduced enemies or natural enemies which have been fostered. The subject has developed to a point which enabled Dr. H. L. Sweetman, of the Massachusetts State College, to write a book of more than four hundred pages.[1]

The work on insect parasites has been one of the most expensive and at the same time most highly profitable research projects which the Bureau of Entomology has undertaken. Unfortunately, the method was of necessity one of cut and try. Men were often sent to remote parts of the world to study parasites and predators of insects related to a particular major pest. If parasites of promise were found they were brought to the United States. After being cultured in captivity, sometimes with serious difficulty, they were released where the pest which they were expected to attack was present and the results followed under field conditions. Many introductions have been successful, but many others have wholly or partially failed. Thus in all cases a large amount of work was necessary to bring the introduction to the final test. Roughly speaking, the failures may well have exceeded the successes, but the successes have been important enough to justify the effort and expense.

This work stands out in sharp contrast to the bungling treatment of the mammalian pest problems of the western grassland and other grazing lands of the United States and Canada. In 1901 C. Hart Merriam chief of the U. S. Biological Survey, in an article in the yearbook of the Department of Agriculture,[2] outlined the *reverse* of biological control of rodents. This consisted of a description of the processes by which the enemies which had controlled the populations of prairie dogs and other rodents detrimental to agriculture had been reduced, resulting in the increase of the rodent populations to pest proportions. At that time it would have been easily possible to set up an experiment dealing with biological control of these pests. On the contrary, however, the use of poison was advocated. This was not new because cattle men of the plains had used poison for many years to control wolves, and the practice had no doubt been followed to some extent in the eastern states and probably in Europe. Dr. Merriam's article appears, however, to have been the beginning of federal

[1] Harvey L. Sweetman, "The Biological Control of Insects." New York. 1936.

[2] C. H. Merriam, "Prairie Dogs of the Great Plains." Yearbook, U. S. Dept. Agr., 1901: 257–270.

KIT FOXES, ORIGINAL ENEMIES OF GRASSLAND RODENTS

THEY LIE IN WAIT FOR THEIR PREY, AS DOES THE COYOTE. KIT FOXES WERE ABUNDANT AT ONE TIME, BUT ARE NOW VERY RARE. THEY ARE ESSENTIALLY HARMLESS TO MAN'S INTEREST.

advice to use poison, the sequel of which was federal support of poisoning undirected by research.

Previous to 1914 the various divisions and bureaus of the U. S. Department of Agriculture, especially the Biological Survey, made studies of the distribution and food relations of birds and mammals, and made efforts to standardize bounty systems for the control of predators in the several states, especially the western ones. In 1914 the Survey secured its first small appropriation for experiments and demonstrations in predatory animal control. These were probably merely experiments to determine what poison method was cheapest and least dangerous. The "experiments" were followed by larger appropriations for control of predatory animals. The intensity of this politico-economic campaign is illustrated by the fact that it was carried so far that the wolves and mountain lions were eliminated from Yellowstone Park, an area set aside in 1872 for the preservation and "retention in a natural condition" of the "(natural) curiosities within the park." These animals had also been given the right to live by an "act to protect birds and animals in Yellowstone National Park" passed in 1894.

It is important to understand at this point that studies which would have thrown light on the question of biological control of mammalian pests call for large areas of land on which the natural interactions of the important animals and plants can be studied. Although the Federal Government had set aside the Santa Rita Range Reserve in southern Arizona, in 1903, for the study of grazing problems, no biotic or bio-ecological

studies were undertaken for many years. However, in 1917 an agreement was entered into by the U. S. Forest Service, the Biological Survey, the Carnegie Institution of Washington and the University of Arizona to conduct cooperative bio-ecological studies with particular reference to rodents which were growing too numerous. This condition of the rodent population is the usual sequel of intensive campaigns of predator destruction such as had just preceded it. Bio-ecological studies were started soon afterwards with attention concentrated on the rodents. One of the early important papers from this source, "The Life History of the Kangaroo Rat," by Vorhies and Taylor,[3] appeared in 1922. It was followed by a goodly series of important researches during the succeeding 15 years. Meanwhile, various other studies have contributed much additional information concerning interactions of plants and animals.

The Grasslands

The outstanding mammal problems of the United States and Canada concern the grasslands of central North America. A discussion of the original condition and history of this area with special reference to animals will facilitate understanding of the possibility of biological control of plains animals. The grassland originally presented an excellent group of animals living in a state of dynamic balance. To the pioneer trappers the immense herds of bison meant free meat and free hides. Bison fitted the climate and grassland so well that *its population exceeded the present human population* on the same area. It is an outstanding indication of greed and prejudice, on the part of man, that it was destroyed so ruthlessly instead of being maintained as a meat producer. The antelope was also an important game animal. Associated with the spectacular ungulates were the wolf, coyote, badger and numerous well-known rodents such as the ground squirrels and the prairie dog. There was also a full quota of small predators such as the kit fox. To fully appreciate the relations of the animal to settlement and the development of pest problems it is necessary to review the history of the fauna during the period of settlement of the grassland area.

[3] C. T. Vorhies and W. P. Taylor, Professional Paper; *U. S. Dept. Agr. Bull.*, 1091: 1–40. 1922.

The Trapper-Hunter

Early period. There was very little exploration and trapping south of the Arkansas River before 1800. North of this point, however, there was considerable trapping and hunting for skins earlier. As to the use of grassland animals other than bison by fur and hide seekers, there is very little early information. Noteworthy records are in the journals of Lewis and Clark[4] and of John C. Luttig.[5] They cover trips from St. Louis across the grasslands. Luttig went to a trading post which was established at the end of the journey up the Missouri River (1812–1813). Lewis and Clark crossed the entire grassland area in 1804–05. The first bison were recorded from southeast South Dakota; the prairie dog and badger were recorded from this area by both parties. There was no mention of the so-called plains grizzly bear in the vicinity of Fort Manuel or Fort Mandan in the central part of the Dakotas. The first mention of this animal by Lewis and Clark was in extreme western North Dakota. The principal furs traded were beaver, otter, muskrat and fox; the principal rough hides were bison, wolf, deer and elk. Since the bison hides constituted a large part of those traded, there was a sharp

[4] R. G. Thwaites, "The Original Journals of the Lewis and Clark Expedition, 1804–1806." Vols. 1–3. New York. 1905.

[5] J. C. Luttig, "Journal of a Fur-trading Expedition of the Upper Missouri, 1812–13." Ed. Stella M. Druman. Missouri Hist. Soc., St. Louis. 1920.

decline in the fur and hide business with the extirpation of the bison, which came soon after 1870. To what extent such species as the kit fox, spotted skunk and blackfooted ferret were utilized is not clear, though Woodhouse in 1854 mentions foxes in connection with the southern plains. Lewis and Clark mention trade in kit fox skins in eastern Montana.

The Cattle Period. During the cattle days, trapping continued as an important vocation on the plains. This is evidenced by the fact that Scotts Bluff (now a National Monument) was so designated for a sick trapper named Scott, who was left behind to die by a group of inconsiderate companions.

Relative to trapping, Colonel Richard Irving Dodge (1883) says:

> When I first came to the "Far West," thirty-two years ago, trapping was still an institution [about 1850]. Generally alone, sometimes in couples, rarely in more numerous companies, trappers ranged the whole country wherever peltries were to be had. . . . It is a common matter of wonder among persons ignorant of the ways of the Plains, how these men could have voluntarily adopted a means of livelihood apparently so full of danger. . . . Each, making his way to the village of Indians most convenient to the territory in which he wished to trap, proceeded to interview the chief whose friendship and protection were gained by generous presents. . . . Other presents purchased one or more squaws and a tepee. He thus became a member of the tribe.

THE STOCKMAN, COWBOY AND CROP FARMER ATTITUDE

Bison were no doubt slaughtered as competitors of the cattle, and 1876 saw the practical end of the bison herds and the Indian that lived by means of them. With the decline of the bison, there was a definite decline of the wolf due to poisoning, which also killed off the kit fox.

In referring to the badger in his study of the mammals of Texas, writing in 1905, Bailey[6] says:

> The cowboys have a real grievance against the badgers, especially those who have been thrown from running horses that had inadvertently stepped in old and half-concealed holes. Such accidents are by no means rare and sometimes they are fatal to both horse and rider. It is hardly surprising, therefore, that the cowboys look upon the badger as a legitimate target for their six-shooters. In a prairie-dog country, however, this is not a fair excuse, for prairie-dog holes are just as dangerous, and each badger helps to reduce the total number of pitfalls.
>
> The rapid increase in the abundance of prairie dogs in certain parts of the State and their constant extension of range is unquestionably due in great measure, if not mainly, to the destruction of badgers.

The consideration of any possible *use* for flesh-eating animals such as the coyote, kit fox and members of the weasel family, including the large burrowing badger, never occurred to ranchers or cattlemen. Bailey has described his experience with certain Texas ranchers at whose request he killed a badger as follows:

> The people had no reason to believe that he (the badger) had ever killed any of their poultry, but they were afraid he would. There were already two badger skins hanging in the tool house on this ranch, while a twenty-acre field of alfalfa was rendered almost worthless by prairie dogs. When I tried to convince the owners that every badger on the ranch was worth $100 to them they only laughed. Some of the ranchmen, however, appreciate the services of the animal, but even then the temptation to try a shot at one at long range or to let the dogs catch one for a fight is often too great to be resisted. Dead badgers are frequently seen by the roadside with smashed skulls or bullet holes through them, and this most often in the heart of the prairie-dog country. When taken to task for their folly in destroying these valuable animals the ranchmen have usually stoutly denied the charge, saying that most of them were killed by emigrants and other "tenderfeet."

Foxes had always been destroyed by agriculturalists in Europe and the eastern states and consequently, anything that looked like a fox, even a small one, was thought dangerous to livestock and poultry. The badger, particularly, "surely must have invaded the poultry

[6] Vernon Bailey, "Biological Survey of Texas," N. A. Fauna, 25: 1–222, 1905.

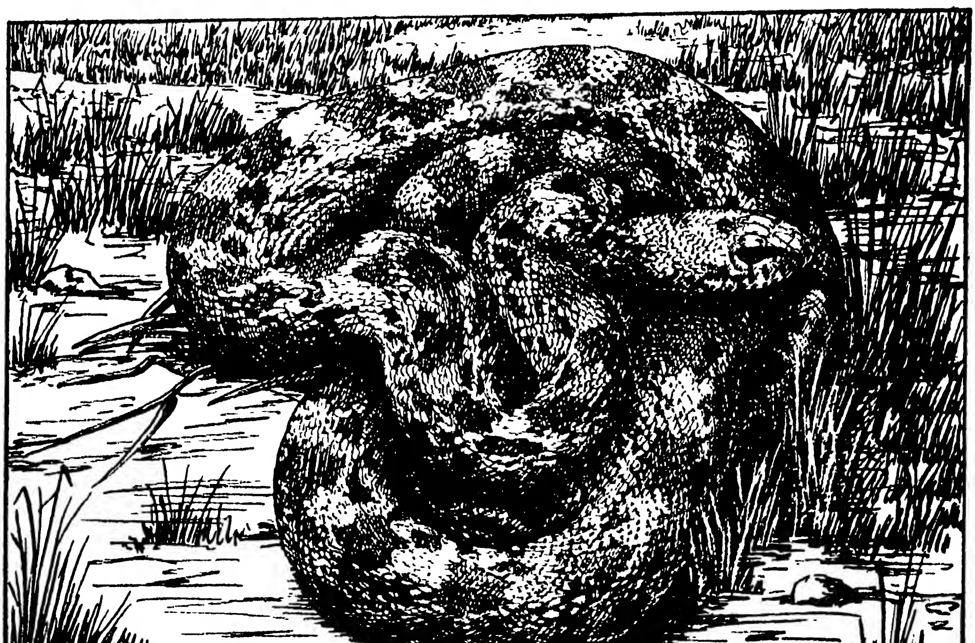
house"—and the ferret and weasel likewise. The destruction of the enemies of the rodents in the grassland went on to a greater degree than it does in the forested areas even to-day. The prejudiced methods were followed without question.

The stockmen felt the increasing losses resulting from their depletion of grass forage, which began before 1890 and from time to time redoubled their long-standing efforts to control carnivorous mammals in the western plains and mountain foothills, chiefly by the use of poison. This involved the destruction of wolves, coyotes and all other animals which will eat poisoned flesh. This was due to their alleged destruction of livestock and game.

Evidence is accumulating that certain rodents increase in numbers under overgrazing and damage grass and cultivated crops in a serious manner. It is the opinion of students of grasshoppers that overgrazing is a cause of outbreaks.

With overgrazing and the destruction of their enemies the rodents of the grassland, particularly ground squirrels, prairie dogs, kangaroo rats and jack rabbits, constitute a problem in grazing areas as competitors of livestock. Their increases on the plains, following settlement, are well described by Merriam in the 1901 Yearbook of the Department of Agriculture:

On many parts of the plains prairie dogs were more abundant in 1900 than formerly and their colonies had overspread extensive areas previously unoccupied. This is due to the aid of the settlers (1) by decreasing the animal's natural enemies, and (2) to a minor extent by increasing the food supply. The settler waged warfare against the coyotes, badgers, hawks, owls, snakes, and other predatory animals which



Redrawn, Courtesy The Macmillan Company

BULL SNAKE—RODENT DESTROYER

ONE SIXTY-FOUR-INCH PACIFIC BULL SNAKE ATE FOUR FULL-GROWN GOPHERS IN ONE MEAL.

previously held the prairie dogs in check. The prairie dogs had multiplied until they had become a pernicious enemy to agriculture.

For example, one South Dakota settler stated that about 1885 his children noticed two or three burrows about a mile from his house, and in 1900 they had spread over and occupied a full quarter section (160 acres), having surrounded his house and taken possession of all the land near it.

The damage done by prairie dogs results in the loss of grass eaten and buried under the mounds.

Merriam cites many examples of losses. A cattle ranch had its carrying capacity cut from 1,000 cattle to 500 by an increase of prairie dogs which extended to cover 300 square miles. In the same area there was a decrease in population and the abandonment of a post office.

Merriam advocated the use of poison to control the rodents, and it was only two or three years after the publication of Merriam's suggestion (1901) of the use of poison that Dr. D. E. Lantz, of Kansas Agricultural Experiment Station, bought more than a ton of strychnine to poison jack rabbits and prairie dogs. It was the rare fortune of the writer to accompany him in May, 1904, when he checked over the decisive results of his strychnine campaign of the preceding summer. Prairie dogs were reduced almost to extinction in the areas where the poison was applied. Enough, however, are practically always left to make a "come-back."

The discussion by Merriam (1901) indicates that the *reverse* of biological control is a fact: "The prairie dog and ground squirrels have several mortal enemies which, when not interfered with by man, usually served to hold their numbers in check. The most important of these were the coyote, badger, black-footed ferret, bull snake and rattlesnake [the last of which the stockmen could not be expected to encourage]. Their methods of attack differ widely (see figures).

The coyote sneaks up to the border of a prairie dog colony or ground squirrel burrow, hiding behind straggling tufts of vegetation. He lies in wait until some unwary rodent comes out to feed, when by a quick rush it may be headed off and caught. The kit fox proceeded in a similar manner. The badger, however, drives his prey into its burrow and then digs it out. His foreclaws are long and strong. [In 1928 Silver reported observations showing the efficiency of the badger in the control of the prairie dog.] The black-footed ferret is built like a weasel, and though much larger, is small enough to enter and traverse freely the burrows of prairie dogs, so that he is able to pursue them to the ends of their holes and capture them with absolute certainty. He is, therefore, one of their most relentless and terrible enemies, and if sufficiently abundant would quickly exterminate all the inhabitants of the largest colonies.

The bull snake (*Pituophis sayi* Schleg.) and the Pacific bull snake or gopher snake (*P. catenifer* varieties) are enemies of ground squirrels. Guthrie[7] says: "One Iowan caught bull snakes and put them in a field that was heavily infested with striped ground squirrels. They completely cleared it of the rodents." The Pacific bull snake is also important as a rodent destroyer. Van-Denburgh[8] (1922) says: "The snake is introduced into the burrow of the rodent and disappears. In a few hours he reappears, languidly crawling into the sunshine, while a huge bulge about two-thirds the way along his mottled body gives proof of what has happened down in the dark underground galleries. One sixty-four-inch Pacific bull snake that was brought to me was handled too much; he vomited four full-grown gophers, none of which was more than slightly digested. On another occasion more than a dozen mice had been swallowed." Nevertheless, the snakes are commonly killed on sight and are easy to see. Mammalogists belittle the effect of the snake, but those who have cared for them in exhibition collections hardly

[7] J. E. Guthrie, *Ia. Agr. Exp. Sta. Bull.* 239: 146–192, 1926.

[8] J. Van Denburg, "Reptiles of Western America." Occ. Pub. Cal. Acad. Sci. 10: 2; 623–1028.

agree. Mr. Bertrand Wright states that a bull snake will eat a Norway rat every five days when confined where but little exercise is permitted. Mr. F. X. Leuth, of the Illinois Natural History Survey, states that the maximum rodent consumption by a bull snake in captivity was seven mice in one day and fourteen mice in one week. This applies to snakes kept inactive and in a relatively cool place.

It is evident from all the literature available that the ferret, kit fox and bull snake are in no way injurious to agriculture and also completely harmless to the grazing interests. The badger does very little damage and a large amount of good. The same is true of other members of the weasel family. Murie[9] has recently shown that the coyote is a beneficial animal in Yellowstone National Park. Likewise, Olson[10] has presented arguments to the effect that the large wolf is a benefit to game and to the forest trees in the Superior National Forest.

Two questions remain: (1) What has been done in the way of biological control of mammals? (2) What can be done to try it out, and what resources are available with which to make the experiments?

As to what has been done—it is only in the past fifteen years that managers of large game reserves have learned that there is something to be done besides killing off alleged undesirable animals and protecting popular ones. Many grazing or range managers have failed to make even that much progress.

In 1936 Vorhies[11] made the following general statement:

> There has been, on some of the erosion projects, a tendency to damn, convict and sentence the rodents to death on a large scale on areas to be worked for erosion control. . . . Surely in an area in which burrowing rodents are so important in the loosening up and aeration of the soil—as in our earthwormless, arid southwest—the little animals deserve to have the possible benefits they confer on the soil carefully balanced against the possible effects of increasing erosion. It may be fairly questioned whether rodents, by and large, are important in causing erosion directly.

He finds that the cost of rodent control is not justified by the benefits, if any, that are received. It is an established fact that under certain conditions, at least, rodents may be more helpful than injurious to man's interests because of their largely beneficial influence on the soil, their serving as a food supply for valuable fur-bearers, and their insectivorous habits.

It is, accordingly, obvious that very little in the way of developing biological control on areas where it might be tried has been accomplished.

During the early part of the poison period, apparently there was no thought of any other method being practicable. In recent years, however, some evidently casual observations have been made by the Biological Survey, and the following is a quotation from a personal communication:

> There are numerous instances where predators, such as the coyote, have remained unmolested and yet the ground squirrel, prairie dog, and jack rabbit problems on these areas have been alarmingly acute. There are areas where rodent populations have been reduced by artificial means almost to the vanishing point and yet, despite the fact that native predators were left alone, the recovery of the rodent population was rapid.

The lines appear to refer to general observations instead of the kind of long-time experiments on land devoted primarily to research that would lead to definite results. The observations made since 1916 could hardly have included more than a third to a half of the original predator species. The populations of such as remain are reduced almost be-

[9] A. Murie, "Ecology of the Coyote in the Yellowstone Fauna of the National Parks of the U. S." *Bull.* 4: 1-206, 1940.

[10] S. F. Olson, Scientific Monthly, 46: 323-336, 1938.

[11] C. T. Vorhies, "Wildlife Aspects of Range Rehabilitation. Hoofs and Horns," N. 5, No. 8: 6-7; N. 5, No. 9: 10-11.

yond recovery. The kit fox, blackfooted ferret, badger and certain snakes are depleted almost beyond recovery in many localities and the first especially is rapidly disappearing due to the poisoning of coyotes in areas where they are still present. The U. S. Biological Survey, during this period of increasing control of mammals from 1916 to 1931, probably had ten to twenty mammal destroyers to every scientific investigator. During this period, poisoning of mammals was possibly looked upon as a means of building up a strong bureau, comparable to the one in charge of insect control.

Status of the Small Predators. As to the resources available, beginning on the northern plains, Jackson, reporting on the mammals of Manitoba, stated in 1926 that the badger population on the grassland portion of the province in 1905 was estimated at 20,000—ten per square mile in some places:

> But cultivation, destruction of gophers, trapping, and poison have reduced the annual catch to 1,000 or so. Badger hair is worth eighty-five dollars a pound, and used in making the best shaving brushes and in faking silver fox by anchoring in white badger hairs, and sold as "pointed fox."

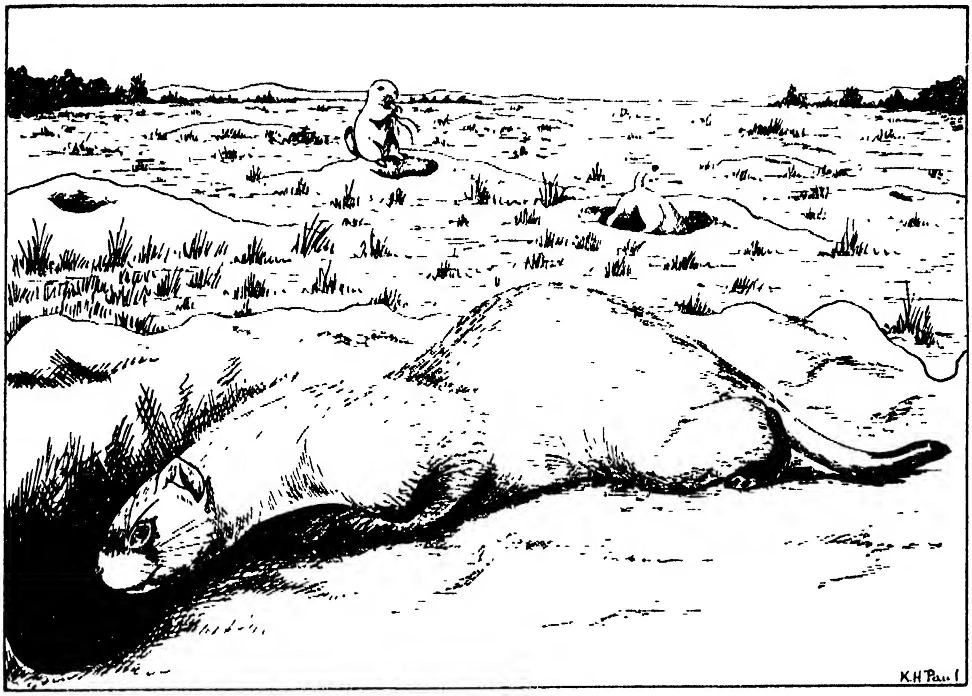
The other prairie provinces have a similar history in this respect. North Dakota licenses the trapping of coyotes, skunks, badgers, weasels and foxes. Wm. J. Lowe, Fish and Game Commission, states that there have been no records of kit fox for some years. A blackfooted ferret was taken in the state in 1935. South Dakota appears to regard the badger as a predatory animal. There trapper wardens instruct men and boys in predator control. The Nebraska Game, Forestation and Park Commission express the view that the kit fox and blackfooted ferret do not occur in that state. Dr. C. D. Bunker, of the University of Kansas Museum, states on the authority of a man associated with the buffalo slaughter that the kit fox was generally destroyed by poison put on buffalo carcasses by cattlemen during the period of buffalo slaughter, 1870–75. One or two blackfooted ferret records in Hamilton County in the western part of the state have come to the Kansas Museum in recent years. In Oklahoma, the badger is uncommon; the kit fox and blackfooted ferret are almost unknown now, but the fox was mentioned by early travelers. The Texas Game Commission reports show considerable numbers of badgers trapped each year. It is evident that there is still considerable farmer trapping which has served to bring about and indicate a very low population of badgers, blackfooted ferrets, and especially kit foxes in cultivable areas. These animals have evidently almost disappeared from cultivated and intensively grazed areas.

However, in the grassland area of Utah and Nevada the kit fox is still reported. Badgers are said to be abundant in some places in central Wyoming and also in Alberta.

Given the necessary land—an area of somewhat more than a million acres fit only for grazing—the animals most highly desirable to restore may exist in greatly reduced numbers. A population develops under protection or can in all probability be restored by transplantation. Such an area should be managed on a hands-off basis and can serve as a place to preserve the great plains big game in a wild state.

One who makes a brief study of the Great Plains big game reserves is likely to be impressed with the fact that the bison and antelope are rapidly being domesticated in all of them due to (1) winter feeding on hay, and driving to winter ranges; and (2) various schemes for regulating breeding and care of young in close quarters.

The reserves are at the same time usually overgrazed to a considerable



BLACKFOOTED FERRET OFTEN FOUND ASSOCIATED WITH PRAIRIE DOGS
THE FERRET, BUILT LIKE A WEASEL, IS SMALL ENOUGH TO CATCH PRAIRIE DOGS IN THEIR BURROWS. FERRETS HAVE ALMOST DISAPPEARED FROM THE GREAT PLAINS.

degree. One of the largest of these, formerly at Wainwright, Alberta, is very badly overgrazed (personal observations, 1939). Here the smaller animals are accordingly deprived of shelter and are wanting or deficient in numbers. Some of them, as the badger, certain smaller vertebrates and various invertebrates were threatened with extirpation. Future generations have a right to see these animals in a wild state. There would be many distressing appeals from botanists if redwoods, beech and giant cedars and other trees with their associated shrubs and herbs were rapidly coming under cultivation as nursery stock, and from bird lovers if several song birds were becoming extinct (see Shelford).[12]

[12] V. E. Shelford, *Science*, 90: 564–565, 1939; *Science*, 90: 591–592, 1939; *Can. Field Nat.*, 54: 5–7, 1940; *Science*, 91: 167–168, 1940.

Research on Plants and Animals

The scientific study of grassland problems of native grasses and especially of animals was long neglected. Down to 40 or 50 years ago, evidently the idea that anything could be learned through the study of grasses had scarcely entered the mind of even scientifically trained people, and the study of animals lagged 35 years behind that of the grasses. An illustration of this point may be seen in the following quotation from Chapline and Campbell[13]: "Range entomology and other special phases of zoological research may be justified where high economic values are at stake. Cases in point include the beet leafhopper and

[13] W. R. Chapline and R. S. Campbell, Research and extension program. In "The Western Range," 74th Congress, Second Session, Senate Document 199, pp. 523–533, 1936.

locust infestations in many parts of the West, where the pests breed chiefly on overgrazed range lands and often migrate to nearby irrigated areas, thus causing great damage both to the range forage and cultivated crops." Such works as that of Wolcott,[14] writing in 1937, to the effect that insects under certain conditions eat more grass in pastures than cattle do indicates the importance of research on plant and animal communities by trained individuals.

Previous to the recent drought and depression, from which recovery is far from complete, there were only two or three range experiment stations in the large climatic grassland areas. When the drought and depression called for scientific study, agronomists quite unprepared to cope with the native grass problems were much in evidence.

That there is a need for a grassland area for use in the study of the original balance in nature on the plains, as a scientific project, is apparent. It should be comparable in size to one of the larger National Forests of which there are approximately 150, more than a third of which exceed a million acres in area. It can at the same time preserve the large ungulates in a wild state and depict the conditions of the covered wagon days.

Grassland offers many advantages over other types. Some of these are:

(1) Grassland allows full visibility of the more important larger animals and plants.

(2) Niches and hiding places for animals, such as tree tops, fallen and hollow trees, and dense thickets do not occur in Great Plains areas to retard observation.

(3) The life histories and life span of the principal plants is about one-tenth that of forest trees and this greatly facilitates observation because of the more rapid turnover and hence the quicker response to climatic fluctuations.

(4) The grassland flora and fauna have intimate relations to the general problems of agriculture and human welfare on the Great Plains.

(5) Grassland constitutes about 40 per cent. of the original vegetation of the earth's land surface and is of great importance to mankind in general.

(6) It has been much less studied than forest.

(7) Stable primeval areas or semi-primeval areas of large size are rapidly disappearing. In another generation the program proposed by biological scientists may perhaps be impracticable.

(8) The field is unencumbered by organized pure science research projects.

(9) It is a vegetation type in which ecological interest is great and much important plant ecological work has been done on the moist eastern portion of the plain but all animal relations and their interactions with plants have been neglected.

(10) The problems of wind and water erosion of soil and the attendant dust movement are essentially biological problems.

(11) Suitable lands are of *low* economic value.

(12) Its climate is suitable for the work of investigators.

A grassland laboratory possesses facilities for research not available in some other types of land, such as forest or agricultural land. The great complication of forest vegetation makes many types of shelter and many niches affording protection from the elements to animals and smaller plants, which render observations difficult. Tundra shares the advantages of grassland for researches involving field observations. These barren lands, however, are in a climate forbidding to continued scientific research and are remote from academic centers.

The plans of interested scientists have called for an undisturbed check area which could be under observation for a

[14] G. N. Wolcott, *Ecol. Monographs*, 7: 1–90, 1937.

sufficiently long period to permit an analysis of drouths and dust storms and rodent, predator and grasshopper outbreaks that occur at rather long intervals of 30 to 50 years or more.

Agricultural lands are subject to such erratic overturn that causes of cyclic phenomena can not ordinarily be followed in a scientific manner. Game preserves and other small areas are, necessarily or unnecessarily, so managed as to obscure natural phenomena and render scientific conclusions unavailable or uncertain. Students of grasshopper outbreaks and, to a lesser extent, infestations of rodents, desire large areas to follow the normal population of these pest animals. The need of a large area of approximately 1,000,000 acres has been voiced by many, including grasshopper specialists, whose scientific results require freedom from *marginal effects* in this migratory group. For example, a tract or a few dozen sections of land surrounded by cultivated and overgrazed areas is so completely sprinkled with wind-borne organisms as to render conclusion as to natural trends uncertain.

Recently there have been efforts on the part of the Ecological Society of America, the National Research Council and the National Park Service to have an area set aside large enough to contribute to all these objects. Other reasons for this have been set forth by Hanson and Vorhies[15] in the March, 1938, number of this magazine and another by Cahalane in the August, 1940, number.

15 H. S. Hanson and C. T. Vorhies, Scientific Monthly, 46: 230–241, 1938.

Summary and Conclusions Relative to the Grassland of the Great Plains of North America

I. The evidences reviewed, including the historical facts, indicate the following:

1. Biological control of pest mammals has never been tried.
2. The essential species are still available but greatly reduced and declining so that a point of extinction may be reached reasonably soon.
3. The several tracts of land of suitable size and present use are available at low cost. A part of each is already publicly owned.
4. The value of rodents as soil builders renders retention of natural populations under biological control in the best interest of soil fertility and the production of grasses.
5. The restoration of the plains fauna on a large tract is desirable from the standpoint of its preservation in a wild state.
6. A large reserve is needed as a check for lands under management. Such a tract can form a basis for an adjacent biological laboratory for the study of bioecological problems, evolution, hormones in nature, the origin of pest populations, etc.

FOOD HABITS OF PRIMITIVE MAN

I. FOOD AND THE CULTURE PATTERN

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The Problem

Our understanding of human nature and motivation has been, and to a large degree still is, almost entirely under the influence of the theory of economic determinism. This theory, together with the aftermath of behaviorism and the crude interpretation of the struggle for existence before genetics revealed the complexities of natural selection, have led to a most oversimplified picture of human conduct. Man was viewed as merely an animal driven by biological forces, dominated by self-interest, *i.e.*, what we think self-interest should be, and generally striving to survive by satisfying his biological urges in a direct and simple fashion. This characterization of man rings so true and seems so reasonable that at first glance students of biology, especially if unacquainted with anthropology, will find nothing wrong with it and wonder why any one should question its validity.

Under the influence of nineteenth century thought it was taken for granted that every primitive custom was generated by a utilitarian cause of a kind we choose to call rational. Satisfactory evidence for the accuracy of such causation could, by the very nature of the case, seldom be presented, but the appeal of this belief pattern was so strong as to make its assumptions go largely unchallenged. It is a fact, however, that current anthropology presents us with a vast store of material proving that primitive man, like his modern brother, invariably acts through the intervention of beliefs, and that these are not always generated by necessity, but on the contrary, may determine what precisely constitutes necessity. In addition, man does, more often than not, go contrary to biology and inflicts pain upon himself and even courts death if some cherished belief dictates that he do so. He may reject good food or even fast for long periods if he thinks it pleasing to some spirit or if he views it as "necessary" for some remote goal, or for no good reason at all. Out of many possibilities he may select a diet that produces a deficiency or inflicts considerable discomfort. Although many wish to explain away these so-called superstitions and irrationalities of the past, as though our modern diet does not have its own "superstitions" and "irrationalities," the fact remains that they exist, and even persist, that they are deep-seated in all human cultures and are as much a part of man's conduct as the family, art or loyalty of some sort. Since they exist they must be studied and understood.

The Scientific Approach to a Prejudice

Scientists do not display exceptional attitudes toward new ideas. Like the vast majority of human beings they find the old and established so comfortable and so wholly consistent with other unquestioned beliefs as to regard it as reasonable. The new, and as yet unassimilated is then necessarily declared to be unreasonable. The following questions were submitted to several hundred trained scientists and to as many laymen. Both groups gave only "reasonable" answers. The questions were: Why did man domesticate the cow? For what

purpose was the chicken first domesticated in Burma? Omitting the Biblical account, how did the day of Sabbath originate? Why were Eskimo women locked indoors during a whale hunt? Why do Jews, Mohammedans, Hindus, some Australian tribes, Micronesians and other groups proscribe pork? Why do Indians forbid the use of beef? Or generally state the reason for any particular dietary taboo or custom.

Few of the scientists questioned were especially familiar with the facts involved in each problem, and fewer still thought that knowledge of such facts was essential. Most of them relied, as a rule, on their reason and when they did so gave invariably the wrong answers. Since the chances are that the average reader will also supply the same answers there is no need stating those given. We shall indicate instead why they are wrong.

The cow was domesticated in Egypt and was originally used neither for meat nor milk nor as beast of burden. Our awareness of the present role of this animal is so fully taken for granted as to blot out all desire to know the facts, thus leading us into false reasoning about the original motive. "Primitive man began to keep animals not with an eye to profit but for the uneconomic though quite human reason that he jolly well liked to have them about as companions and for entertainment," says R. H. Lowie. One may even go further and say that the first domesticated animal, the dog, was not really domesticated by man. On the contrary, it was the dog that domesticated man. Early excavations show canine bones some distance from human camp-fires, indicating that he lived near human sites as scavenger. Later ones show remnants of man and dog together. Presumably, by loitering long enough near human camps the dog taught man conviviality with animals.

The fact of the matter is that man domesticated every animal he could lay his hands on, but discarded those that proved unamenable as pets. To quote from the same author:

> Pet-rearing ultimately gave way to exploitation because man is not a total abstainer from common sense if he indulges with fanatical moderation. He noted that the animals he sheltered from the struggle for existence came to differ from their wild brethren in point of size, hair, and other features. Some of these traits he prized as desirable and bred for. Thus trends that set in under the novel conditions were intensified: wooly and fat-tailed sheep, milch cows, egg-layers sprang into being. But this utilitarian frame of mind came last not first.

From Egypt the culture element of the cow diffused to India. There the cow is still a sacred animal, though when India adopted the cow, milking had already become a custom and came with it. China received the cow before dairy products had been developed but used the animal for beef. In Africa, where cultures abound to-day which sanctify the cow and have milk and dairy products as their staple food, beef, too, is eaten, though exclusively on ceremonial occasions and at that by the wealthy only. Much of East Africa subsists on agriculture, "but," writes Melville J. Herskovits, "the number of cattle owned by a man correlates highly with his position, for position here, as in most societies, is related to wealth, and cattle are the sole expression of wealth. It is of no consequence how much cultivated land or other goods a man possesses, for should he not have adequate resources in cattle he can have no place among the wealthy. . . . Cattle are eaten only on certain ceremonial occasions, or when an animal dies, nor have they any other utility aside from that of supplying milk, since they are never employed as beasts of burden." As we shall see in all these cultures, man's relations to the cow, to her milk and to the process of milking were weighted down with severest ritual.

Chinese sources indicate that the chicken was first domesticated in Burma, where it was used for purposes of divination. A bamboo splint was inserted into

the perforation of the femur and by the angle of inclination one peered into the future.

Cockfights were popular in Burma. To settle disputes a cockfight was arranged, and the owner of the winner was adjudged right. Even to-day the Wahuma of East Africa and other tribes single out chicken meat for special contempt, regard eggs as feces and prescribe purgatives and segregations for any one who eats them even by mistake. Yet each family of any consequence raises poultry and not for fun or sport but to satisfy a potent and time-honored need. Chickens are dissected, their entrails exposed and from their convolutions all that the future holds in store for the individual or the community is deciphered. While most of us do not display this unquenchable anxiety about the future, with primitive man it was an obsession. Whatever phenomenon showed variation was exploited for divination. Stars, comets, eclipses, hands, figures on the ground, shapes, the flow of water, the flight of birds, facial muscles, dreams, bones, entrails, fires, clouds, leaves, plants and what not.

It should be noted parenthetically that while these acts of divination brought man in contact with specific bones and their intimate structures, for example, foramina, these led to no development of anatomical or physiological knowledge. This fact brings to mind a similar situation in Egypt, where embalming meant some familiarity with human anatomy. The Egyptian priests and medicine men developed expert embalming methods but not a trace of a science of anatomy.

Speaking of the domestication of the fowl can not but bring to mind the case of the turkey. It was the only domesticated North American animal, excluding the dog. The Hopi of Arizona were one of the few tribes that raised it but not at all for food. They kept it for its feathers. The Aztecs, however, used the turkey both for its meat as well as feathers and also ate the dog, which the Hopi did not. Both tribes were mainly agricultural.

The answer to the next question the reader may find in any anthropological text. Suffice it to say here that rest days in general were introduced as acts of mourning or fear, as sit-down strikes against an unfavorable fate rather than as rest from hard labor. Continuing with the questionnaire and dealing with those questions which have a direct bearing on food we come to the fourth which is answered by the following quotation from a work by Peter Freuchen:

> There are a number of native superstitions about whale hunting as there are about everything. From olden times there has been a gentleman's agreement between men and whales that no woman should be present at the hunting. This resulted from a legend that at one time a woman harpooned a whale and thereby insulted all whalekind and kept them away for many years. When I was in Hudson Bay an old angakok had revived the tradition, and no woman was even permitted to be outside her tent while the men were hunting whales. I saw them disappear when we set out. Only old ladies past the age of fertility (and therefore regarded as men) could run about from tent to tent relating what was happening out at sea.

The remaining questions deal with dietary taboos and these constitute a problem in themselves. Before considering them, however, let us point out that the scientist who has not devoted time to a special study of each specific taboo will invariably follow the folklore of our time and attribute a modern cause to its origin. In other words the scientist like the layman will be governed by a dominant belief or theory and tend to explain away precisely those aspects of reality which need study. Both are convinced that their explanations are based on reason and both will condemn the mustering of contrary facts as befuddling and petty quibbling. This mode of approach may justly be termed superstition or magic. The scientist who argues that domestication followed consciousness of

need and was utilitarian in origin, or that taboos stem from practical motives simply speaks from ignorance of primitive man. As in the superstitions of the past, forces and causes are postulated that do not exist but are believed to be real with a show of logic and reason. The method of science demands different procedures.

The Tyranny of Belief over Diet

Primitive man lived his life within his culture pattern very much as we do. To judge him at all is bad enough but to judge him by our standards is unadulterated folly. Just as we are guided by our beliefs, values and assumptions, so did he use his reason and followed his daily pursuits on the basis of his beliefs, his values and his assumptions. His values were, of course, different from ours and he tended to question or challenge them far less than we do. More particularly, in ignorance of the method of science which constitutes a mighty weapon in our life and thought, he failed to employ and improve his mode of approach, as we constantly strive to do, and was left at the mercy of uncorrected groping and blundering.

Regarding food, all primitive cultures displayed one common peculiarity still present to a significant extent in our own scientific era. Primitive man enveloped his diet, his eating etiquette, cooking and all functions pertaining to food, in a network of habits and regulations, theories and fears, obligations and ritual. These were strong enough to exert a powerful influence over his respective culture pattern for thousands of years. The dietary prescriptions of the Bible may serve as a familiar illustration. All animals with uncleft hoofs and not ruminating were declared taboo and impure. So were fish without fins and scales, all worms, crustacea, molluscs and most birds. No argument relating to the evil quality of the forbidden food is given or to the nature of its effects upon health. It is merely stated that "they shall be an abomination unto you," and are "unclean." The text continues:

> All fowls that creep, going upon all four, shall be an abomination unto you. Yet these may ye eat of every flying creeping thing that goeth upon all fours which have legs above their feet, to leap withal upon the earth . . . the locust after his kind, and the bald locust, and the beetle after his kind, and the grasshopper after his kind.

Particular stress is laid upon the admonition, "Thou shalt not seethe a kid in its mother's milk," since we find it mentioned three times in the Pentateuch. There seems to be weighty evidence besides, presented first by J. G. Frazer, that it was one of the original ten commandments.

Equally interesting and representative are the dietary rules of India. Here too proscribed food is considered "unclean" and "an abomination," and dietary notions are inextricably merged with the problem of caste. Thus a Brahmin regards as polluted all water or food touched by any one not in his own caste, hence inferior to him. Even the shadow of a lower casteman falling upon food renders it polluted and uneatable. Madras Brahmins regard food as polluted which had merely met the gaze of a lower casteman. Not only is such food considered unclean, but it must not even be thrown away lest others eat it and suffer unconscious pollution.

The role that food plays in the caste system can be seen from the following:

> Where a certain caste can not eat food cooked by another caste, while the latter permits food to be eaten which was cooked by the first caste then the first caste is superior to the second. . . . If a Brahmin accepts water from another caste that caste is considered clean in Bengal. If he accepts food cooked in oil, then the caste is still better. . . . Clean castes do not pollute water; but below them are castes which pollute water; below them are . . . castes which pollute an earthen vessel, then castes which pollute a brass vessel.

Moreover, food is a significant factor in caste degradation. Some castes are

degraded by eating meat, by drinking wine or smoking tobacco. Consumption of pork, beef and fowl are considered wholly degrading to most castes.

The taboo of intermarriage is sufficiently real to us within our own culture in so far as it affects members of the white and Negro races. To Hindus it is made a thousand times more real since its prohibitions involve individuals of different castes, of which there are over three thousand. Equally real to Hinduism is the taboo of interdining. This term describes the rare event in which two members of different castes defy custom and eat together. So important is the act of eating that interdining between members of castes not even far apart in status, leads to a family tragedy of equal possibilities and dimensions as may intermarriage in our society.

Central and Eastern Africa are mainly populated by Bantu tribes. Many of these are non-agricultural and have milk as their staple food. Cattle is venerated by almost all cultures though there are few indeed that eat beef at all, and these do so only on rare occasions. All work relating to dairying and care of cows is performed by men. It is a heinous crime for a woman to come near a cow or be near the kraal at milking time, or touch a vessel containing milk or even touch a man who is about to milk or has just finished milking. Women's main tasks are washing the earthenware milk pots with cows' urine, and churning to make butter. The latter is quite an industry, though butter is used little as food but chiefly for anointing the body.

Only "chiefs and wealthy men add beef to their milk diet," and that only on rare occasions. "Usually the night intervenes after a meal of beef and beer (which must follow beef) before milk is again drunk. There is a firm belief that the cows would sicken should milk and meat or vegetable mix in the stomach." Vegetables are seldom eaten, in fact only in times of extreme milk shortage "when pressed by hunger. . . . During her menses a woman may not drink milk, except from an old cow past bearing; should her husband fail to procure such a cow she eats vegetables until she is well again." This prohibition too is rationalized by the claim that it would be injurious to the cow.

Milk must be drunk fresh and never boiled, "as the boiling would endanger the health of the herd and might cause some of the cows to die." For the same reason "the meat of goats, sheep, fowls and all kinds of fish is deemed bad and is absolutely forbidden to any member of the tribe" (The Banyankole).

In most, if not all pastoral tribes, "cultivation of the ground is regarded as injurious to their cattle" and all manual work as degrading. This contempt for agriculture is reminiscent of the Biblical attitude toward Cain. It also finds ample expression in the Iliad. But be the tribe agricultural or pastoral, cattle is everywhere virtually holy. Among agricultural tribes "the principal use of cows is to obtain wives." "Cattle are money among the Wanyika and they prefer to save their cattle to barter for a higher order of chattel (in their eyes)—women." "They give more care to a sick calf than to a sick wife," continues the author, L. J. Vanden Bergh. "Barring the absence of a roof, the enclosures sheltering the cows are better built than their own huts." As a rule the eating of meat is not prohibited but is too much of a luxury. Only chiefs whose rank varies with the number of cattle they possess can afford it. Poorer people need their cows, goats or sheep to purchase wives or pay taxes. All meat when eaten must be roasted on a spit since it may not touch a pot. It is cut into small pieces "about two inches square" so that the chiefs, the only ones to eat meat, need not exert themselves in tearing or biting off pieces.

Cows yield only about five pints of milk daily and much of it is given to the

calf by command of ritual. A cow may not be milked until the calf has had its share and the udder must not be emptied since some milk must be left for the calf. Should the calf die, its skin is preserved and produced each time the cow is milked. In addition cow dung is put to many practical and spiritual purposes in building fires, religious ceremonies and medicines.

Since milk must not come in contact with beef or vegetables in man's stomach, so as not to bring certain death to the cattle, proper intervals are observed between the consumption of these items. After eating vegetables, some tribes, such as the meat-eating Masai, wait forty-eight hours until milk may be drunk. Beef, eaten only by chiefs, among most Bantus and at that on rare occasions, may be consumed only at night and must not come in contact with any milk vessels. No milk may be drunk until the next day. It should be noted that contemporary orthodox Jews still observe similar restrictions, the so-called kosher laws. After the consumption of meat no milk or cheese is permitted for six hours and two hours must elapse before meat may be tasted after milk. The two kinds of foods require two sets of dishes and tablecloths and even an unintentional error is regarded as a serious offense against God.

Women may not drink any milk at all during their entire period of menstruation unless they are rich enough to have cows that are definitely past bearing. At that such milk must be kept apart and may be used exclusively for menstruating women. Women in childbirth are allowed to drink milk only if the baby is a girl. If it is a boy then the mother may drink milk from a cow that had lost her calf. Under no circumstances may milk be boiled or warmed, kept near a fire or brought in contact with metal. In passing it should be noted that while some tribes, *e.g.*, the Baganda, never drink milk fresh but clotted, others make use of it in all forms while still others drink it only fresh. The prohibition of boiling seems widespread and also the admonition to keep milk away from metal vessels or objects. In this connection it may be noted that with the Hottentots the system is reversed. Women do the milking and men concern themselves little with the cattle. In the summer the tribe subsists almost exclusively on milk, yet men are forbidden to taste sheep's milk. The death of a cow is a major family tragedy foreboding evil and often leading to the owner's suicide. Tonics and medicines for cows are far more highly developed than for humans and native religions provide more gods to care for the requirement of cattle, their health longevity and fertility than for the needs of men.

Practically all Bantu cultures permit beef of animals that died a natural death. Usually it was the only beef they ever could eat. Not so the laws of the Bible. "Ye shall not eat of anything that dieth of itself; thou shalt give it unto the stranger that is in thy gates that he may eat it; or thou mayest sell it unto an alien: for thou art an holy people unto the Lord thy God. Thou shalt not seethe a kid in his mother's milk." Giving away prohibited food must be regarded as a great social boon. Many are the cultures that demand the casting away of all food left over after a meal. In many cases "No remaining food was kept or put aside for another meal." In addition, strangers among the Bantus must never be offered any milk lest it mix in their stomachs with vegetables or meat and thus afflict the cattle.

Whatever the practice, the reason given is always the same, the protection of the cattle. Boiling milk is bad not for the consumer but for the cattle. Should a menstruating woman drink milk the cow would surely become sterile. Among many Bantu tribes, *e.g.*, the

Banyoro, the belief prevails that it is immoral for any man or woman to till the soil or indulge in any agricultural work because such activities are injurious to the cattle. Bathing or even washing at all is prohibited on the ground that it would hurt the cattle. Among other tribes the woman is permitted to do agricultural work while the husband attends to the cattle and dairying. Other cattle-revering Bantu like the Baganda may "live entirely upon plantains and despise all other kinds of food." Everywhere, however, as in Biblical and Homeric times herding is highly regarded and agriculture is looked upon as degrading. Furthermore, the kraal must be provided with a perpetual sacred fire properly guarded. The cows must be milked in a definite order and in specific positions with regard to the fire. Generally speaking there are few acts involving cows or milk that are left unregulated but the peak is reached with respect to the royal herd.

The Banyoro king is revered by the people. He rules not over the land but over all the cattle. His major food is milk, though he may occasionally eat beef of an evening, never in the daytime. Under no circumstances may he eat vegetables or mutton. From his numerous cows a special herd is selected to supply him with milk. These cows are sacred and must not mingle with others. They are tended by a carefully chosen boy known as the "Caller" because "he had to call out to warn people to leave the path as he passed along with the cows." This boy was picked for the job when he was seven and kept it until he married. If he took sick and the royal physicians declared his illness critical he was strangled to save the cattle. The same fate was meted out to him if he became unchaste or had blood drawn by a prick or scratch. Those who struck or offended him were similarly treated.

All men employed to care for the cows had special titles, obeyed strict rules of chastity and could not wash with water but butter. The collection and transport of the king's milk, his way of drinking it, the handling of leftovers, the washing of the dishes, in a word, everything was surrounded with rules and taboos.

Serving the king beef was similarly regulated. He was not allowed to touch it with his hands and it had to be put into his mouth with wooden prongs. Meat could not be boiled in vessels but was roasted on wooden spits.

Courtship all over the land regardless of rank was conducted with cattle. To have status in the community a young man must acquire cattle and thus be in a position to woo his first wife. After the choice is made and the girl willing, her father begins a long process of bargaining and extracting as many herds of cattle from the young man as his wealth and his desire for the girl permit.

In spite of the fact that milk is so wide-spread a food throughout Africa, areas are nonetheless encountered in which a different attitude prevails. In parts of the Congo, milk was tabooed by all and regarded with great abhorrence. "Any one drinking it was considered unclean for several days and was not allowed to eat with his family. They could touch milk, for they milked our goats and sheep and carried it to us without suffering defilement, but it must not touch their lips. A boy of nine was known to have drunk some milky water out of a glass, and he was not permitted to eat with his family for five days. They could give no reason for this but only stated it was their custom." Incidentally, the very manner of drinking is of great import. This may be noted in the Biblical story of Gideon as well as in the Hindu custom of throwing water into one's mouth since lips must not touch the metal cup.

The ancient Egyptians, as was also noted by Herodotus, tabooed the flesh of

cows. Priests were allowed beef of steers but could taste no fish which they regarded as polluting. Beans were proscribed to all as was also pork which like the meat of many forbidden animals could be eaten ceremonially on certain holidays. Pork is still proscribed to hundreds of millions of human beings of the Hindu, Mohammedan and Jewish faiths and beef to some two hundred million Hindus.

In passing it should be noted that contemporary Jews are not permitted to eat the lower half of a cow and do not consider even the anterior half as kosher unless all major blood vessels are removed, since blood is considered a special "abomination." For meat to be kosher it must come from animals killed according to the ritual law. The same applies to the followers of Islam and the observation "some of them (Somali) died rather than take food which would have saved them because it had not been killed according to Mohammed and rites" speaks for hundreds of millions of men of many faiths.

(To be concluded)

THE FINEST SHOW ON EARTH

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If you were given the opportunity of viewing again one single scene from all those that you have enjoyed, that constitute memory's picture book of the past, which would you choose? Would it be one which portrayed the awe-inspiring grandeur of a total eclipse of the sun or possibly one which recorded the glowing, changing colors of an alpine sunset? Or would you turn to a page showing the brilliant patterns of a New England landscape when the days are growing short and your breath rises lazily before you? While a total eclipse and a sunset are passing fancies on the part of nature, lasting for moments or minutes at the most, autumn foliage in eastern North America clothes the hills in brilliant vestments for weeks at a time.

To what are these colors of autumn due? The ordinary cells of plants owe their green to two pigments, called "chlorophyll a" and "chlorophyll b." These can be extracted from the leaf with warm alcohol, and the solution becomes a deep rich green, a green that through long association with us on this earth has become soothing and restful to our eyes; no color seems quite so pleasing as that of chlorophyll, no color is so important, since only plants that contain this can manufacture foods, for themselves and for us. In addition to the two chlorophylls, two other pigments are also present in ordinary leaves; these vary from yellow to reddish orange. One of these, carotene, is common in carrots—a scientific justification, it has been suggested, that "carrots are good for the complexion." The yellow and orange pigments are less complex, chemically, than the green chlorophylls, and they are also more stable. When the weather gets cold in the fall, the green colors, which break down more easily, tend to disappear, and then the yellow and orange, which have been present all along but masked by the others, become visible. These are largely though not entirely responsible for the golden tints of autumn. These four pigments together constitute only a minute fraction of the fresh weight of the leaves—about twenty-six hundredths of one per cent.—a very small fraction when we

consider how important they are, especially the chlorophylls. There is another group of soluble yellow pigments which are not very significant in fall coloration.

Most striking of the colors of autumn are the reds. These are due to an entirely different group of substances, called the anthocyanins, compounds associated with sugars, dissolved in the cells of the leaves. These vary from the brightest scarlet through all the shades of red and magenta to the deep blues and purples found in some leaves and many flowers. Simple experiments show that the color of these substances depends partly upon the amount of acid present. If the center of a head of red cabbage, which is rich in these anthocyanin pigments, is cooked, and to the liquid obtained a little vinegar is added (vinegar is acetic acid), the juice of the cabbage will become bright red; if a little ammonia is poured in, the solution becomes blue to yellowish green. The greater the acidity, the deeper the red color will be.

Various factors are responsible for the development of these red and blue pigments. First there is the genetic makeup of the plant. Maples inherit the ability to manufacture these substances, while hickories do not; the petals of the buttercup are never red, while those of the scarlet sage rival the faces of the most highly embarrassed.

For the most part, light is important in the formation of the anthocyanins. The sunny side of an apple is brighter than the shady side; the "stem end" is more richly colored than the "flower end." Perhaps in days gone by you pasted your initials in opaque paper on green apples, and when the fruits ripened there were the letters in green on a background of red. The more modern version of this, as described by Arthur, is to paste Cellophane on a green apple, put India ink marks on the Cellophane, and then expose the apple to a suitable lamp; the skin of the apple shaded by the ink remains green. Photographic negatives have been printed on the skins of apples in shades of red and green, using sunlight as a light source.

It has long been known that red leaves of the Virginia creeper contain more sugars than green leaves on the same plant collected at the same time. In 1899 Overton put the leaves or leafy stems of various plants, such as some species of lily, of holly and of columbine, into sugar solutions, and after some weeks they became red. Injured branches of trees often become bright red, while the rest of the tree is still green, presumably because the sugars manufactured by the leaves are not transported away, and consequently stay where they are made. Abundance of sugars favors the development of the red pigments.

It is common knowledge that brisk weather—without prolonged frost—is conducive to rich coloration, and experimental work supports this general observation. Both with leaves and flowers this is true. A blue bellflower and a red primrose were pale, almost white, when grown under warm greenhouse conditions. Cool weather, though preferably not too frosty, stimulates colors in autumn leaves as well as in healthy youngsters.

Though abundant water favors the growth of plants, it does not result in brilliant coloration. Of course drought is fatal, but a degree of dryness toward the end of the season results in beautiful colors. Experimentally this can be shown by watering sparingly some plants that are "vulnerable," and by watering others lavishly; the former will have the red pigments more strikingly developed.

Although leaves rich in sugars are often brilliantly colored, plants growing in soil abundantly supplied with nitro-

gen are often just green. In general both leaves and flowers of northern plants are brightly colored, due to the strong light and low temperatures. However, in 1902, Wulff, collecting plants far above the arctic circle in Spitzbergen, found that in some areas visited by northern birds and fertilized by their excreta, which are rich in nitrogen, the plants were a healthy green, while the same species, growing in poor soil, were brightly colored. Anthocyanins develop best when the supply of nitrates is limited, even if the other conditions are favorable, suggesting, perhaps, that opulence and loveliness do not necessarily go together.

All these factors are important in the formation of these red-blue pigments, known as the anthocyanins. Normally they do not act separately, but through complex interrelationships, and there are exceptions to all of them. Although light is so important in the formation of these substances, the root of the beet, which develops in the dark, is rich in anthocyanins. But in dealing with living things there are always exceptions—little touches that make life worth while.

The drab brown colors of the late autumn, those of the sere if not the yellow leaf, result largely from still another group of substances, the tannins, or from compounds related to them. These are the same materials that are derived from the bark of certain trees, especially oak and hemlock, which are used in the tanning or hardening of leather. Tannins are almost universally present in the higher plants, though generally not in quantity sufficient to make their extraction practicable.

When the green pigments break down in the fall, the yellows which have been present all along become visible; simultaneously the reds and blues develop in certain plants so that various combinations and color effects are produced. After all these have disappeared, the brown remains—the brown that is destined to form a part of this good earth.

Most important of all our trees in producing the vivid colors of autumn, particularly in northeastern United States, is the sugar maple. Sometimes this is just yellow, but more often red pigment is developed, especially toward the tips of the branches, where the illumination is most effective. This tree is the one which is tapped in the spring, and from the sap maple syrup and maple sugar are obtained. It forms extensive groves, especially in New England, and is really the king pin in the coloration of the north. There is a brilliance to the red of the sugar maple that is unrivaled in any of our other trees—a brilliance that gives it an animation and almost a touch of light-heartedness that rather belies the temperament of the sturdy people with whom it shares the soil. In swampy areas similar effects are produced by the red maple, though it, too, may be just a bright yellow.

Associated with the sugar maple are the birches, especially the white birch. These are normally yellow in the fall, and it is common to see the gold of the birches and the red of the maples standing in sharp contrast to the dark green of the white pines and the hemlocks; such contrasts make the colors appear all the more striking. This is especially true in New England, where the "murmuring pines and the hemlocks" are so wide-spread. The aspen leaves also add their touch of flickering yellow, while the waxy barks of the white birches presage the snows that lie in store.

The rolling hills and ancient mountains of our northeastern states form a perfect setting, so that the trees for miles around may be seen at a glance—as if to make it easy for us to enjoy the sight. The hills and valleys and lakes and streams also offer a variety of conditions—of soil, of moisture and even of temperature, and so are important in pro-

ducing diversity and intensity of color in plants growing close together, even in plants of the same species.

South of New England the center of the stage is held not by the sugar maple, but by the oaks. The warm reds and reddish browns are furnished mostly by these trees. Each species of oak adds its own touch to the general pattern. By far the most brilliant is the scarlet oak, which amply justifies its name in the fall. Not a striking tree otherwise, the scarlet oak passes unnoticed until it takes on its cloak of autumn, and then it stands out like one whose modest virtues have been unappreciated. There is a whole galaxy of oaks in eastern North America, each of which typically ripens into a color that is largely its own. The white oak, whose staunch timbers have been used so extensively in shipbuilding, often has leaves red above and white underneath. When they blow in the breeze, the tree presents a curiously changing color pattern. Pin oak may assume an orange-brown color; chestnut oak becomes a bright yellow; black-jack oak may be brownish red, but more often is a glossy light brown, suggesting the leather of new riding boots; red oak passes from green to yellow to brown, while black oak soon becomes a dull brown. In spite of all these variations in the oaks, and in spite of the brilliance of their coloration, compared with the sugar maple there is a slight touch of the sombre in their effects.

While the maples and oaks form the theme of this symphony, the variations are provided by many of our other trees. Dogwood, white or pink at blossom time in the spring, is just as pleasing in the fall, with its red leaves and red fruits; and dogwoods are found from Maine to Florida and west to Texas. Along the banks of streams, and in low ground generally, the sour gum and sweet gum are often seen. These may also be red, or they may be clothed in royal purple. Sour gum is one of the first trees to turn in the fall—a harbinger of the great display to come. White ash may be yellow, or it is sometimes reddish or bluish purple. Sassafras, whose roots are sometimes brewed into a tea, especially in the spring, and served (under protest) to children, adds its tone of bright orange to the drier hillsides. Like the dogwood, it is widely distributed in eastern North America.

While these trees wield a giant brush of red and purple, others, such as the chestnut oak, are responsible for the brilliant yellow. Hickories, especially saplings, often show the touch of Midas. There are hillsides on which the tulip tree grows that look for all the world like the pot of gold at the end of the rainbow. The tulip tree is one of our oldest trees, geologically speaking. It has literally come down through the ages. In the Blue Ridge country it gets as much as two hundred feet in height and ten feet in diameter. Also adding its light yellow to the autumn landscape, especially in the haunts of man, is the Ginkgo, maidenhair tree of the Orient. With its fan-shaped leaves and exotic type of branching, it seems indeed like a tree of the Far East, especially to an occidental. It is known definitely only in cultivation, having come to us as a temple tree from China and Japan. Once found growing wild clear across the northern hemisphere, it has aptly been called a "living fossil," for it alone survives of an ancient group that has otherwise passed. Seward has suggested that each year, for a short time, its leaves reflect the glory of that golden age when it flourished so abundantly.

Last of the trees to turn is the black cherry. Rather appropriately, it takes on all shades, from yellow to deep red to dark purple—a fitting résumé of events that have transpired, and all the more striking when, in November, the skies are often dark and even the noon-

day shadows are long. At this time, too, the steel-gray bark of the trunks of the beech stands in marked contrast to its light brown leaves.

Although trees play the major rôle in this whole display, shrubs also contribute, especially the sumachs and the blueberries. Most of the sumachs, like the dwarf and the smooth, become bright red or scarlet. At times, though, the staghorn sumach, whose twigs are downy like antlers in spring, takes on all the colors of the rainbow, from violet to red, sometimes in one leaf, and almost in one leaflet. "Infinite shades of color," says the artist; "gradual changes in acidity," says the scientist.

Related to the sumachs is the poison ivy, usually a vine, but shrubby at times. Its leaves are often bright red, in contrast to the ivory white fruits. The latter look like simple symbols of purity, though they are poisonous. Boston ivy shows similar color effects in the leaves, but without a trace of malice.

No other shrubs are so common in eastern North America as the blueberries; some of them are to be found growing in dry soil, while others inhabit swamps and bogs. Almost universally they turn a bright red in the fall; they may augment the colors of the maple, the oaks and the sour gums, or they may stand in sharp contrast to the green of the pitch pine, the southern white cedar and the mountain laurel. Due to the oaks, sumachs and blueberries, much of New Jersey looks toward the end of October as though some giant had passed through the countryside with a single large pot of red paint and had applied it lavishly. Barberry, including the cultivated form, becomes a bright, slightly rusty red. On Cape Cod and in New Jersey the cranberry plants in the bogs turn a dull, reddish purple after the fruits have been picked; at the same time glasswort splashes its vivid red against the brown of the grasses in the salt marshes along our coast.

In dry, rather sandy soil the grasses, especially the beard grasses, may be seen bowing in unison to let the breeze go by. These also become colored in the fall, forming reddish brown carpets on the hillsides. Very slowly do they fade, so that the tints of autumn may still linger at Christmas time; and these grasses often stick up hopefully through the first thin snows. Only long after the winter silence has descended do they fade into a pale yellowish brown.

Not a little is added by the fruits that ripen in the fall. Bittersweet sprawls and twines and shows its orange capsules and scarlet seeds; hollies, growing in swamps as well as in sands, mature their red berry-like fruits; barberry bushes are often laden with red; while hawthorn, after the leaves are gone, shows brilliant red against the blue of the autumn sky.

These are some of the more important contributors to that symphony of color that is played each year on the hillsides of North America. If there is a "hard-frost" or a pronounced "dry-spell," the performance is syncopated, leaving the dark green of the pines and hemlocks and spruces enlivened only by the barks of such trees as the birch, the beech and the red maple.

The brilliant display of autumn is really the result of two sets of factors: one is the wonderful assortment of broadleaved trees in the East, capable of developing these colors; the other is the weather—the clear, bright days and cool, crisp nights that are so characteristic of the fall in our eastern states. "Football weather" is conducive to brilliant foliage, as well as to husky voices on Sunday morning.

On what parts of the earth does this coloration occur? There are only three large areas of temperate broad-leaved

forests on this earth—one in eastern North America, one in eastern Asia and one in Europe, including central Europe and the British Isles. In the southern hemisphere such forests are almost lacking, except for a small region in southern South America, mostly in Chile, and very limited areas in Tasmania and New Zealand.

Eastern North America and eastern Asia are strikingly alike in their plant populations. It may seem rather anomalous that floristically there is a greater similarity between eastern North America and eastern Asia than between our own East and our own West. No places on this earth have a richer assortment of valuable broad-leaved trees than eastern North America and eastern Asia. Our West has matchless forests of conifers, like the pines, Douglas fir, redwood, and hosts of others. In fact, many of the lands that are washed by the waters of the Pacific are rich in conifers. But the West is relatively poor in broad-leaved trees. Climatically, eastern Asia, including much of Japan, is also similar to eastern North America. Consequently, it is logical to find that these two regions both show brilliant colors.

On the other hand, much of northern Europe has cool, damp, cloudy weather in the fall. This is not so true farther south, so that in the Danube valley beautiful foliage does occur. In parts of the Alps, due mostly to shrubs, the colors are also pronounced.

Continental Europe, furthermore, does not have the wealth of broad-leaved trees that occurs in eastern North America, though many of the missing species will grow there if planted. In fact, many of them are found in Europe in fossil form. When the glaciers came down from the north in the last ice age, the plants in North America advanced south before them. Our mountain ranges run north and south, so that this was possible. In Europe, when the ice sheets came down, the flight of the plants was impeded, since the mountain ranges run mostly east and west. Local mountain glaciers advancing probably made the escape still more difficult, and consequently many of the trees perished. The sweet gum, the tulip tree, the hickory and the sassafras, for instance, grew in Europe until the last glaciation. This is known from fossils. Partly because of climate and partly because of the relative paucity of broad-leaved trees, Europe does not have the display that we have here. Eastern Asia largely escaped the last glaciation, while Greenland and Antarctica have not emerged from it to this day.

One topic more might be discussed—namely, the significance of coloration in plants. It is well known and generally accepted that insects are attracted to flowers partly on the basis of their color, though bees, like many men, are red-green color blind. Young leaves unfolding in the spring often show the same tints that are developed in the fall; and it has been suggested that these pigments serve to absorb light and thus raise the leaf temperature. Others claim that the pigments act as a protective screen against certain rays of light that may be deleterious in various ways.

While these last two explanations may possibly be of some significance in autumn coloration, it seems hardly probable that the development of these striking colors in the late fall is very important to the plant. The same trees may get along perfectly well without them, and often do. It appears more likely that the conditions are favorable, the stage is set, and the show goes on, without any deeper significance. Perhaps this is the botanical expression of "art for art's sake." In any event, it is a gracious way of saying good-bye.

THE NEW PUBLIC HEALTH[1]

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FIGURES presented by Dr. Louis I. Dublin, of the Metropolitan Life Insurance Company, indicate that the percentage of the population of 65 years and over exactly doubled from 1860 to 1930—a rise from 2.7 to 5.4 per cent. in a period of 70 years.

According to estimates by Thompson and Whelpton the percentage will again more than double between 1930 and 1970—a rise from 5.4 to 11.8 per cent. within a period of but 40 years.

The predictions of statisticians in this field must be taken seriously. If the actual average length of life turns out to be less than that expected, life insurance companies stand to lose money. Consequently, figures usually err on the safe side. Thus a percentage of 6.3 was anticipated for 1940. When 1940 rolled around the census that year showed an actual percentage of 6.8.

The sudden doubling in the relative number of old people is taking place rapidly. Between 1930 and 1940 the total number increased 2,322,401. The increase in this group was 36.5 per cent., as compared with a 7.2 per cent. increase in the entire population. In some parts of the United States (Dutchess County, N. Y.) the percentage of old people predicted for 1970 has already been surpassed. Just 29 years hence we must therefore expect more than four times as many fathers- and mothers-in-law of 65 years and over to care for as our forefathers had to look after at the time of the Civil War. In round numbers there will be 12 in place of 3 per hundred.

[1] These data, and many others mentioned in this paper, will be found in a book entitled "Problems of Ageing," edited by me and published by the Williams and Wilkins Company of Baltimore.

Because female mortality in adult life and especially at older ages is less than that of males, Dublin expects that the majority will be mothers-in-law. A factor in the development of this sexual disproportion, which he does not mention, is that the majority of women do not have to survive the same sudden and awful shock that men are subjected to when retired. Females slip into inactivity more gradually and therefore more safely than males.

In the suburbs of our cities have sprouted like mushrooms thousands upon thousands of tiny houses built to accommodate a man and his wife and perhaps two children. The larger houses of a generation ago are slowly disintegrating. As a result, the old people will be squeezed out of life with their children and grandchildren.

It is important to realize that the second doubling will be effected during the lives of young men and women now in our universities and at the threshold of their careers. What will be their attitude to the problem of caring for this vast throng of aging relatives? Their most impressionable years have been in the era of the New Deal, of unprecedented spending, during which the government has taken over from individuals and from localities responsibility after responsibility. My guess is that they will, with hardly a thought, continue passing the buck to Uncle Sam.

Already an effort to buy a solution by spending has assumed vast proportions. Under the Federal Security Act of 1935 our legislators are simply placing millions of dollars in the hands of the aged where they remain for but a short time. If one half of one per cent. of these

sums could be devoted to trying to find out how the aged can best be helped, the effectiveness of the 99.5 per cent. would be greatly increased.

As so often happens, a private organization took the lead. In 1939 the Josiah Macy Jr. Foundation, under the presidency of Dr. Ludwig Kast, published the results of a systematic survey of the problem. Encouraged by the foundation, the U. S. Public Health Service established a division of gerontology under the able direction of Dr. E. J. Stieglitz. A new kind of public health is being conceived. It is a union of what is best in medicine and sociology.

Wholesale methods are being supplemented by retail ones. Among the former we at once think of measures which have benefited the whole population and have been largely responsible for the rise in age level: improved water supply, improved foods, better living conditions, vaccination, and so on. It is to be noted that individuals profit almost passively. No particular effort on their part is required. But the retail methods, which are gaining momentum, involve on the contrary the closest cooperation between the patient and physician over long periods of time.

Of first importance is adjustment of the individual, both mental and physical, to the changes that occur in his or her body with aging. These changes we shall refer to later. It is the privilege, not of any governmental agency, but of the medical profession everywhere to aid in the adjustment. What is needed is a return of some physicians to the old-time rôle of guide, philosopher and friend. Unhappily this is made increasingly difficult by the onrush of specialization and the rise of great departmentalized clinics, undeniably good things in themselves. It can not be doubted that what many old people fear, more even than disease and death itself, is the prospect of having nothing to do, of uselessness, of being a handicap on their children. Perhaps the greatest economic and humanitarian contribution of public health in the future is to maintain socially useful activity as long as possible in this very large fraction of the population. In the words of Dr. G. M. Piersol, the goal is "to add more life to the years rather than more years to the life."

While keeping an eye on the liabilities of aging people we must cultivate their assets, which are too frequently ignored. Shakespeare put these words about aging, where they belong, in the mouth of a fool. "And so from hour to hour we ripe and ripe, and then from hour to hour we rot and rot, and thereby hangs a tale." Aging is for Emerson a shedding process: "these temporary stays and shifts for the protection of the young animal are shed as fast as they can be replaced by nobler resources." When we follow up this idea certain facts emerge.

Most aging people past 65 have presumably shed preoccupation in their own careers and responsibility for bringing up their children. They have also shed some of their physical activities and, having retired, possess more time for activities on the higher mental plane. Their outlook on life has changed, but it is unlikely that any one will fully understand this outlook save the aged themselves. If they would speak up it would help a lot. But there is evidence of increasing interest in others and of increasing tolerance of the actions of others. Likewise a breadth of view resultant on experience is noticeable and a new dignity. They become concerned unselfishly in the future in which they will not play a part. They may acquire wisdom. This is, according to Miles, "the characteristic prerogative and contribution of well-preserved age" recognized, we may add, by all the greatest civilizations of Greece, China and other lands and not to be forgotten to-day.

Nature is kind to them. The sensation of pain is often dulled. Both Rolleston and Critchley have called attention to this fact. And for the vast majority death is, in the words of Osler but "a sleep and a forgetting."

Of secondary importance to adjustment to changing manner of life, though I do not like to admit it, is the shift in emphasis which is taking place from acute to chronic disease. I do not mean that investigation of acute infectious disease should be for a moment relaxed, but that chronic disease is now recognized as the greatest danger. In 1930, 59.8 per cent. of white men aged 60 could look forward to death from cardiovascular renal diseases and 10.7 to death from cancer. For white women the figures were slightly different, 59.5 and 11.9 per cent., respectively. To-day the expectation is more gloomy.

Two points are worthy of emphasis. First, the deaths are not quick, as with infectious diseases; but eventuate slowly, which means a tremendous amount of incapacitation and economic loss to the tune of billions of dollars. Second, the warning signal of pain, often provided by nature for other kinds of injury, is lacking in the early stages.

It is reliably stated that if cancer were painful at the beginning, treatment could be instituted promptly and thousands of lives could be saved. But it may be a mercy that the onset of cardiovascular renal disease is not generally heralded by pain because the period of sickness is longer and the site not localized and susceptible of surgical removal. Moreover, the means of diagnosis of early cardiovascular renal diseases are better known.

Because apathy concerning cancer was so widespread, Congress, on the insistence of Surgeon General Parran, unanimously passed the National Cancer Act. This provides for the National Cancer Institute and for small appropriations to stimulate research by private organizations and individuals. In respect to cardiovascular renal disease, it was the far-sighted Macy Foundation that again made the first detailed examination of research possibilities. But there has been no follow-up. The financial support necessary for research is still lacking.

There are other problems requiring immediate action, of which mention will be made of only one, that of nutrition. Much has been learned about the proper food of individuals in the upswing of life, nothing about that of those in the downswing. This downswing begins before the age of 65 years. It is probably well started at 45 years. In 1940, more than 25 per cent. of the population were 45 years or over. And we complacently remain ignorant of their nutritional requirements in this land of surpluses!

Basic, of course, to public health of the future is detailed information on changes in the body with age. Only in the light of such data can we guide individuals so that, as far as their hereditary endowments permit, they will be enabled to live healthy and useful lives. The task of astronomers, physicists and mathematicians is simplicity itself compared with that before us. While they have to consider a few variables we have them without end. Our concept of the body is that of an aggregate of billions of vital units in unstable equilibrium constantly changing in continual adjustment to environment both external and internal.

No part of the body remains the same throughout life. Many tissues, no longer needed, are discarded. In early life the "before" kidney is succeeded by the "middle" kidney and this in turn by the "after" kidney. The fetal cortex of the adrenal wastes away. Great veins become fibrous cords or entirely disappear. After about a year there remain in the nervous system no short-lived

nerve cells capable of division. Later on, many other sorts of primitive cells drop completely out of the picture.

To provide for wear and tear the larger part of the body is being constantly renewed. With the passage of years, life is maintained by an ever-changing cellular population. The rate of replacement is not uniform but differs for almost every cell type. For some it is rapid; for others very leisurely. No one has yet classified the cell types in order of increasing rate of turn-over. Either the stimulus to cell division is different for each type or the responsiveness of each type is different for essentially similar stimuli. However this may be, replacement of cells in the human epidermis is rhythmic (Cooper and Schiff). The number dividing by night is about twice that of those dividing by day.

Looking further we see an almost endless vista of other and different rhythms, some long, others short; some of great volume, others small; but all related in some way to each other. W. F. Petersen has considered biological rhythms in a very penetrating way. He has called attention to the fact that over a century ago Ernst von Baer compared life to a melody in which rhythm is made up of increases and decreases in functional activity, while harmony and disharmony reflect well-being and disease. To put it differently, not only the radial artery but all tissues pulsate each after its own fashion but not independently, and the whole changes with age in ways that we can imagine but imperfectly.

Coming back to our theme, the parts of the body which are not replaced are likewise of great variety. They include dead and living components. We think at once of dental enamel, of which the replacement is nil. The elastic coats of blood vessels are not effectively replaced, though other elastic fibers form. Nerve cells, cardiac muscle cells and many others, once differentiated, must serve to the end. Among the factors of safety are durability, numerical excess of cells and the duplication of mechanisms. These non-replaceable parts change with time, each at a tempo peculiar to itself and in a host of different ways, most of them unknown.

No two bodies age in the same way, except to some extent those of identical twins. Aging, like dying, is a piecemeal process but slower. One system or organ may outstrip the rest. Different parts of the body have different life spans. Life span is defined as the potential duration of life under the most favorable conditions. The life span of the eye, according to Friedenwald, exceeds that of the body as a whole, while that of the vascular system is obviously relatively short.

Rate of aging is conditioned by factors too numerous to mention, but the chief ones are the inseparables—heredity and environment. The grip of heredity can be felt at almost any age and in various sites. Whether lethal genes exist, as in certain lower forms, remains to be determined. In mice premature and delayed aging of the joints is hereditary, as the Silbergs have demonstrated. There is some reason to think that the rate of aging of vital rubber in the arteries is partly conditioned by heredity. As our knowledge expands, it becomes evident that the fate of many parts of the body is similarly predestined.

The entire body may be fortunate or unfortunate in the hereditary control of its aging. It is known to all of us that the members of some families, male and female, barring accidents, live to a ripe old age without taking any particular care of themselves. But a common factor can be dimly discerned. Some work hard and others little, some are soaked in nicotine most of their lives and others are free from it, yet all, generally speak-

ing, take life complacently and do not habitually worry. They are well adjusted to their physical and social environments. Others would like to be and aren't.

Adjustment to the external environment—involved though it is—is relatively simple compared with adjustment to the internal environment. As we grow old both begin to fail. The response of the endocrine symphony to its conductor, the pituitary, becomes less harmonious with change in the individual pieces. The nervous system frequently drives the rest of the body beyond its dwindling capacity into the grave. This large changing picture of adjustment is a consequence of what is happening in numerous small localities.

All the cells of the body that are alive are aquatic. With the exception of those that live in the streams of blood and lymph or border them, they are all inhabitants of the extra-vascular tissue fluids. Evidence is fast accumulating that these local tissue fluids are not of essentially uniform composition, as W. B. Cannon would have us believe. They are said to be simply ultrafiltrates from the blood. But this is to view them only from one angle and to ignore the fact that living cells reside in them. These cells differ in different localities, and it is not to be expected that they will influence all the tissue fluids in the same way. Moreover, local differences in endothelial permeability are known so that it would be surprising if the ultrafiltrates were of uniform composition. As a matter of fact the chemical composition of subcutaneous tissue fluid, cerebrospinal fluid and aqueous humor of the eye, to mention only three, are distinctly different. It is safe to predict that many other differences will be found, just as we anticipate other rhythms in cell division and other sites of hereditary control of aging.

Of the alterations in these many tissue fluid environments with age, very little is known. If those containing multiplying replacement cells should remain favorable, the presumption is that the descendants of the cells in question would continue in series indefinitely. The reason for this statement is that when some cells of this sort have been removed from the body and have been cultured in appropriate media frequently changed, they have gone on living in series indefinitely. H. G. Wells has truly said parts of Mahomet could be living to-day had they been cultured through the ages in this way. Similarly, when certain malignant cells have been transplanted from animal to animal, the strain of cells has continued alive far beyond the life span of the original host. But owing partly to changes in tissue fluid environments these cells, if confined to the body, die off with age.

Increasing difficulty in the attainment of reasonable stability is the most outstanding feature of aging. A release from controls begins to make its appearance. This is seen to best advantage in the skin. In the epidermis we find areas of hyperplasia and atrophy, of pigmentation and depigmentation, of hypermineralization and hypomineralization. The stage is set by this wavering and instability for the occasional malignant change. It is possible that the same process is at work unnoticed in other deeply situated tissues.

But my time is limited. My immediate purpose has been to give a dynamic sketch of a few of the basic changes in aging of the body. Only the surface of the problem has been skimmed. When we dig more deeply and try to follow the aging of individual cells in their several fluid environments we become bewildered. It clarifies the situation a little to divide the cells into two large classes. The first is made up of those whose individual lives end not by death

but by division into two new cells. These I call intermitotics. They include basal cells of the epidermis, the forefathers of blood cells, spermatogonia of the testicle and many others. They are the replacement cells already referred to. In them, as individuals, it is difficult to find signs of aging though such probably exist.

The second consists of cells which become highly specialized, leave no descendants, age and die. They are by contrast postmitotics. They include nerve cells, cardiac muscle cells and numerous others. It is in them that the signs of aging are most manifest.

Length of cell life, conditioned by factors almost wholly obscure, is within limits characteristic of each type. Preliminary calculations show that individual nerve cells live approximately 2,190 times as long as neutrophile leucocytes. As they age, some kinds of cells become dehydrated, while others do not. Some grow larger, while others decrease in size. Some accumulate pigments altogether absent in others. Many lose specific functions not possessed by others, and so on almost *ad infinitum*. Even death comes in a multitude of different ways depending upon kind of organization, manner of life, vital hazards, etc. And there remains the ever-present task of distinguishing between normal aging and the results of injury and disease at all levels in organization from individual cells, inanimate fibers and tissue fluids up through the organs and systems to the body as a unit.

In brief, however, length of life appears to be limited mainly by the wearing out of the non-replaceable components, nerve cells, muscle cells, elastic fibers, etc.; by hereditary defects or inadequacies in many systems and organs; and by gradual decreases in adaptability to change which may manifest themselves in a wide variety of ways.

Obviously, no single mind can compass even what is now known of the aging of the human body. Fortunately, sociologists, economists and psychologists are meeting the challenge side by side with physicians. The problem presented by this steady increase in the number of aged people is without precedent in history. It is the great problem of the twentieth century.

The tragedy is that old age is *tabu*. A few years ago I was greeted with a smile when I admitted that I was interested in the phenomena of growing old. To-day I am taken more seriously by my younger friends, particularly the pediatricians. But old people often remain their own worst enemies. They are the most grateful of patients. Many hide their heads in the sand, wait like sheep for sickness that could be avoided or made more bearable, give millions of dollars for the medical care of children, whom they find it refreshing to think about, and blind themselves to the welfare of others in their predicament. I am convinced that the problem of aging will never receive the attention it deserves until the best informed among the millions rapidly aging themselves see to it that darkness is dispelled by research. The immediacy of the problem, the second numerical doubling of the fathers- and mothers-in-law, is generating in this country a new public health in which the aged, who have been for centuries the forgotten ones, will share.

SOCIAL NATURE OF SCIENCE

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1. Science After the World War

When the present World War is over there will be many demands for a "tribal" scapegoat in which all blame can be centered. There will be an effort, in true primitive style, to shoulder the blame on many of the obvious elements in the international conflict. One aspect of the tremendous destruction of life and property that is bound to attract attention is the rôle that science has played in war. There is already a strong, rapidly-spreading belief that wars would be ended if science could be curbed.[1] The tragedy of this situation lies in the fact that this belief is based on a misconception concerning the true social nature of science, a misconception created in part by scientists themselves. Those scientists who steadfastly refuse to recognize science as a social phenomenon but insist that it is an extra-cultural phenomenon, an absolute that has its meaning within itself, invite an attack on science. These scientists ignore the origin of science and the process by which it came into existence. Science is not an outside agent or force but a part of social life which is a unified whole.

As the social nature of science is revealed in this discussion it will be demonstrated that science *per se* will not destroy civilization nor can it save civilization since it does not have its meaning within itself. It can, however, be utilized with equal facility in either direction. Just as science is needed to carry on modern war, it will be essential for establishing peace in the type of world in which we live to-day. This point will be clarified as the social nature of science is revealed.

2. The Origin and Social Nature of Science

"If science is not a social phenomenon it is nothing."[2] That statement by a biological scientist does not have to remain a mere affirmation, its veracity can be established through an analysis of the origin of science and the process through which it developed. It is a matter of historical record that science did not always exist. Its advent into the social world is recent enough to discover how and why it made its appearance. Like all other aspects of social life, *science* and *everything* connected with it are all products of interactive living.

There was a time when there was no social life and no science. These accom-

[1] Edwin G. Conklin, "Science in this World Crisis," *Vital Speeches*, 5 (1939), p. 334: "There is at the present time a rising tide of denunciation of science for having produced the disorder of society and the savagery of modern wars that are threatening the destruction of the fairest products of civilization. The outcry against science was begun by the theologians of several centuries ago; it was continued by defenders of classical education during the past hundred years; and since the beginning of the century it has been taken up by the self-styled 'humanists'; of late there are signs that all these denunciations of science as the destroyer of peace, progress and ethical values have begun to influence the minds of the masses of mankind. . . . More than forty years ago Woodrow Wilson discoursed eloquently on 'The Bankruptcy of Science,' and within the last decade Christian Gauss has warned us of 'The Threat of Science,' and numerous other advocates of the humanities have proclaimed that civilization must be saved by curbing or removing science and by promoting 'humanism.' . . . One week ago (*New York Times*, February 19, 1939) a speaker warned the National Conference of Christians and Jews that curbs on science are urgently needed and that it may become a Frankenstein monster if unchecked."

[2] Paul B. Sears, *The Biologist*, 21: p. 3, 1940.

plishments had to wait until the biological process had produced a species with the capacity to develop human nature and live on a cultural level. Once this was an achievement, the interactive relationship among the members of this species set in motion the social process.[3] Everything found in social life, now or at any other time, was either produced in the social process or was brought into use from the natural environment through this process, that is, through interactive living. Science is not an exception.

When the student of social life discovered that everything in social life was either produced through interactive living or was brought into use from the natural environment in the same way, he began to look for the common denominator in social life. He found this to be the interactive relationship between human nature and social organization. In other words, anything produced in the social process or brought into use from the natural environment is integrated into human nature and social organization. Nothing biological, physical or social has any meaning apart from these two factors, and these two factors have no meaning apart from each other. Thus these two interactive elements make up the common denominator in which science and all other products of interactive living have to be explained.[4] No matter where one makes a cross-section of social life he finds these two factors in interaction with each other.

3. Science As a Social Habit

When the interactive relationship between human nature and social organization was a reality there was need for social habits through which these two phenomena, in their interactive relationship, could become functional. Science is one of these social habits. There are many others, corresponding to the many differentiations in human nature and the social order. Some of these are marriage, education, religion, medicine, law, art, music, agriculture, industrialism, food-habit systems, drinking, magic, war, vice and crime.[5] Each one of these came into existence just as soon as there was human nature and social organization that could be expressed through it. At one time the existing human nature and social organization could be expressed through magic and all other unscientific social habits. In the development of these two fundamental aspects of social life there eventually came a demand for science as a social habit through which these phenomena could be manifested. In other words, there was an accumulation of human nature and social organization that could no longer be expressed through pre-scientific social habits.

Science did not exist in the nature of things waiting to be discovered. It could not become a reality until there was human nature and social organization that could be expressed through it. It has not appeared in those cultures where it

[3] The social process is interactive living on a cultural level. It is the means by which social life is established, maintained and changed. Everything in society was either produced in the social process or was brought into use from the natural environment and given meaning through interactive living. As a part of social life the natural environment is a product of interactive living in the sense that it is in this process that it gets its meaning. The data of the physical and biological sciences are social phenomena in the sense that they have no meaning apart from the social process.

[4] Human nature consists of attitudes, ideas, interests, desires, habits and a philosophy of life. It is the subjective aspect of social organization. Social organization is everything of a structural nature, in relation to which human nature has developed. It includes institutions, organizations and all that was produced in associative living as well as everything in nature that has been given an operational place in society. Natural resources as well as general geographical factors have their functional meaning in human nature and social organization.

[5] All these social habits are abstractions until human nature has been expressed through them.

is not demanded by human nature and social organization. In one culture the natural environment is something to investigate, understand and explain; in another it is something to fear and worship. In the former there is a demand for science, in the latter this social habit is not needed. Magic will do. There are no data in the physical and biological sciences apart from the interactive relationship between human nature and social organization. Apart from this relationship what are physical resources, physical units, electricity, magnetism, the atom, the amoeba, protoplasm, cells, tissues, virus, germs, the solar system, telescopes, heredity, genetics, paleontology, the anatomy of plants, etc.?

Like war and other social habits, science is a human invention, the product of interactive living. It is not what it was when it first appeared since the human nature expressed through it now contains knowledge that did not exist when science first appeared. It will be somewhat altered in the future as the interactive relationship between human nature and social organization changes.

Not only science but everything connected with science is a product of the social process, of interactive living. For each social habit there is a group of specialists, trained to direct and to help to determine the nature of the social habit. Once magicians, priests and philosophers were the chief functionaries in relation to social habits, but when science became a channel through which human nature could be expressed, scientists were produced in the process of interactive living. There is not one method by which magicians, priests and philosophers are produced and another by which scientists are produced. The process is identical in a general way. They are all the results of associative activities. They all became what they are through the development of attitudes, ideas, interests, desires and other human nature attributes. They are social products in the same sense that militarists are social products. Social variants, specialists who keep such social habits as vice and crime operating, were produced through the same general process. It is not possible for any individual to develop his human nature outside the social process of interaction.

"The fundamental proposition is that scientific research is a social process as much as business, political or religious activities, and as such is interwoven with all other social processes, influencing them and being influenced by them. . . . Scientific research, then, is one among many social activities carried on by the people of our culture."[6] It is a human creation, a historical development, and will be whatever man decides it is to be. It will always take the functional form that the interactive relationship between human nature and social order gives it. Since science is a cultural pattern, a part of an interactive whole that includes many other cultural patterns, it is distorted when there is social disorganization in the totality of which it is a part. It is perverted in the same way that family life, religion, education, business or any other factor is perverted. What seems to be the perversion of science is really the perversion of the interactive relationship between human nature and the social order being expressed through science.

Many scientists are ready to regard science as a social habit in its utilitarian form but rebel against having the "pure" science of the laboratory so regarded. However, life is a unified whole, nothing exists in isolation. "Scientific work interlocks from one end of the scale to the other."[7] Science for the purpose of discovery can not be separated from science for utility purposes,

[6] W. C. Mitchell, *Science*, 90: p. 604, 1939.

[7] Julian Huxley, "Science and Social Needs," p. 17.

except in a philosophical sense. In the laboratory the research specialist is expressing his human nature of scientific attitudes, ideas, knowledge, desires, interests, etc., through science; thus it is a channel for the expression of human nature even when its chief function is discovery.

In Nazi Germany where civilian science has become military science both in the laboratory and through an aggressive war, one can see the interlocking relationship throughout scientific work. The relationship between pure science and practical science can be seen in any country in the field of medicine, agriculture and in industry. Furthermore, the same scientist could go into his laboratory one year to discover something to preserve life and the next year enter the same place of research to work on a formula that could be used to destroy life and the third year retreat into the laboratory without caring what the social consequences might be. In all cases he would use the same scientific technique and in all cases science would take the form of the human nature expressed through it. Apart from the interactive relationship between human nature and social organization science is just an abstraction.

So science and scientists are social phenomena, likewise everything connected with the activities of this social habit and its specialized functionaries. The techniques, the terminology, the symbols and all else identified with these social products had their origin in interactive living. It was in the social process that man decided what science should be, what it should study and what it should not consider. Scientific interest and curiosity had their origin in social interaction and programs of research center around social problems that need to be met.

All data, whether they were produced in the social process or were brought into use from the natural environment, are parts of social life. Physical and biological data have no meaning apart from the interactive relationship between human nature and social organization. Nothing is studied until a demand arises in social life. There are no physical or biological data *per se;* they have their meaning only as they appear in terms of the socially acquired knowledge about them.

4. Connotative and Denotative Meanings of Science

Like all other social habits, science has a broad connotative meaning or function and many denotative meanings. The general connotative rôle of science allows for the expression of human nature and social organization. Then there are as many denotative meanings as there are differentiations in human nature and social organization that can be manifested through science. The scientist can express his human nature through it but so can a dictator, a criminal or any one interested in destroying life and property.

The denotative meanings are almost as numerous as the great variety of human activities. Science is used by human beings in a social setting to secure control over everything produced in the social process and everything brought into use from the natural environment. It is used by human nature and social organization to get control over three important processes: the biological, the geographical and the social. Man uses it to understand his own place in the universe, to satisfy his socially produced desires for manipulation, to relieve his curiosity and for the pleasure that he gets from using his socially defined intellectual processes.

There seems to be almost no limit to the great diversity of uses for this social habit. In some situations one observes human nature searching for knowledge,

superior knowledge, tested and retested and systematized. In another relationship, questions are being answered about the origin and nature of things with an effort to explain reality and get rid of delusions, superstitions and to eliminate error. It may be a way of thinking, of testing a hypothesis, of discovering laws and unifying principles or for making classifications, predictions and interpretations. Human nature may be expressed through science to achieve safety, to lead to inventions; and quite as important, human nature may be expressed through science to preserve or destroy life.

5. Science is Neither Normal nor Abnormal

Science *per se* is neither normal nor abnormal. As a social habit, the product of interactive living, science is amenable to the expression of any type of human nature and social organization. It is this unlimited range of flexibility that makes science the great social habit that it is. Its greatness is revealed in the expression of destructive human nature quite as much as it is when constructive attributes are manifested through it. Later, it will be pointed out that much of the destructive human nature and social organization expressed through science was produced in the first place through other social habits that have social approval.

Science has no cultural favorites and no preference in types of human nature. The functional nature of science makes it limiting and permissive but not mandatory in nature. The control of science does not necessitate a single change in the nature of science *per se*, but it does depend on the modification of the interactive relationship between human nature and social organization. When science made its appearance as a social habit, war was already a cultural pattern; political and religious conflicts were well established; the idea of exploitation was not new; there were already ancient prejudices, hatreds and many misconceptions about life. Few people saw life as a cooperative quest, or rights as human rights. Rights were the prerogatives of certain groups; they were not human rights. This was the nature of the social life that was ready to be expressed through science or any other social habit when science appeared in society.

One need not be surprised to see science taking the form that a totalitarian state demands. Like any other social habit, it has to take the form that the interactive relationship between human nature and social organization gives it. Science and scientific research emerge out of the growing needs of society, whether that society is a democracy, a totalitarian state or any other way of life. In each one of these forms of government scientists go into their laboratories to meet the needs of society. Even in peace times some governments spend almost as much for poison gas research as they do for medical research.

Science can have no objective functional existence apart from nationalism, apart from the historical religious and nationalistic hatreds of Europe and Asia, apart from such misconceptions as a pure, superior race that has a right to subjugate other groups. Science has no objective existence apart from the imperialistic ambitions of the past and it can have no existence to-day apart from the aggressive attitudes and imperialistic plans in the Orient and the Occident. Science, as a social habit, can be used for the aerial destruction of life and property and sabotage in every conceivable form. War, viewed from one angle, is the utilization of science to express the interrelationship that exists between human nature and the social order. War is the utilization of science to express human nature in its patho-

logical aspects and to make functional such cultural patterns as nationalism, economic exploitation, political subjugation, imperialistic ambitions and all other forms of economic, political and cultural pathology. Science has no chance to escape any form of social disorganization. But remember science did not produce all the human nature that is expressed through it. Any type of pathological human nature now expressed through science existed before science was a social habit. The control of science will be achieved only when there is social control of the interactive relationship between human nature and the social order.

6. Science and Other Social Habits

The necessity for recognizing science as a social phenomenon is seen when there is a realization that much of the destructive human nature and social organization expressed through science was developed through other social habits. Prejudice, hatred, intolerance, delusions of persecution and accusatory attitudes demanding a vindictive outlet, revealed through science and war, were developed in religion, in family life and in education. For instance, neither science, war nor the Nazi way of life placed the Jews in a position to be persecuted in Germany. Nor was their economic supremacy the chief cause of their persecution. Long before science was a social habit, the church, the home and the school placed the Jews in this position, not only these fundamental institutions among Gentiles but among Jews as well. This is not a criticism of these fundamental institutions *per se*. They take any form that the existing human nature and social organization give them.

The point here is that science is often blamed for human nature produced in other habits. The theologians, humanists and others often attack science for human nature produced in their own fields, in non-scientific social habits. Science as a social habit has no functional existence apart from non-scientific social habits. It is well for the scientist to realize this if he does not want science blamed for behavior that came to actualization in other social habits, but this means recognizing the social nature of science.

In a life that is a unified whole, all of which was either produced or given meaning through interactive living, science can be mobilized for a single purpose along with other social habits. There is a total war at the present time with the entire interactive relationship between human nature and social organization pointed in this direction. Science, pure and utilitarian, is now a much used social habit for the prosecution of war. Education, religion and other social habits are mobilized in the same fashion. All these can be used when social life is organized for peace.

7. The Future Rôle of Science

There is one way to predict the future of science, either as a pure science or as a utilitarian science. This can be done only through a knowledge of the interactive relationship between human nature and social organization. It was evident to any student of social life that science would be mobilized for the destruction of life and property in Nazi Germany and Japan. The human nature of a whole generation was marked by hatred, ideas of persecution and grandeur, and accusatory attitudes demanding a vindictive outlet. The interacting social organization was militaristic in nature. How could any one do other than predict aggressive war in that situation, with science and all else mobilized for war? War is inevitable when the proper interactive elements are present and peace will be just as certain when the interactive relationship between human nature and social or-

ganization tends strongly in that direction. Social prediction is possible, just as possible as prediction in any other field.

Prediction concerning the future functional nature of science depends on knowledge concerning the character of the interactive relationship between human nature and social organization. More than this, the control of science depends on the control of this interactive relationship that gives science its meaning. Despite these facts there are still some natural scientists who believe that the interactive relationships between human nature and social organization are not even data to study, understand and explain. A biologist recently remarked that there is not a field of sociology.[8] This statement shows a naive conception concerning fields of study—a belief that academic disciplines exist in the nature of things waiting to be discovered. Actually they exist only in the minds of men. There is a field of study when individuals mark out a certain area of life and give it a name. The boundary lines between all present fields were drawn elsewhere at the outset. Doubtless new boundaries will be fashioned and some disciplines may disappear and others may be established in the thinking of men.

The same biologist who does not believe that there is a field of sociology thinks there is a discipline of anthropology, not realizing that the anthropologist studies the same general types of phenomena studied by the sociologists. The anthropologist studies the interactive relationship between the human nature and social organization of a preliterate group while the sociologist studies this interactive relationship in our own society. Primitive man is produced in the biological process in the same way as man elsewhere is produced and belongs to the same species as all other human beings. His social organization and human nature are achieved through interactive living in precisely the same way that these phenomena are produced anywhere.

The natural scientist encourages the study of social life among primitive groups but may not want his own social milieu investigated. Yet it is here that war, vice, crime, exploitation and other forms of social disorganization are integrated on a large scale. It is here that science is perverted and becomes the social habit through which personal and social disorganization are expressed. It seems incredible that a scientist should object to the study of the phenomena that determine the operational nature of science. If the phenomena studied by the social scientist disappeared there would be no science. If these are not understood and controlled science may be used to destroy civilization—all of social life.

A scientist lives in a social life that is a unified whole and needs, therefore, a connotative mind as well as a denotative mind. He needs the latter for research in his own field and the former so that he may recognize the broad perspective in which his own field exists and see the essential relationships between all fields of study. A scientific mind regards every aspect of life as a phenomenon to be studied, understood and explained. A scientific mind does not want any misconceptions existing regarding any aspect of life.

Some physical and biological scientists do not want to recognize the fact that

[8] Sociology describes the social process, revealing its origin and nature, and shows how each aspect of social life was either produced in the social process or was brought into use from the natural environment and integrated into human nature and social organization. In addition to this general function sociology analyzes and explains the cultural aspects of the interactive relationship between human nature and social organization as distinguished from the economic and political aspects. There is a field of sociology only because a group of specialists marked out an area of life that was not being studied by any other group.

science is a social phenomenon. They want to raise science above the process in which it was produced and above the situation that gives science its meaning —an insuperable task, of course. Nothing in life can transcend the interactive relationship between human nature and social organization and nothing can be placed below it. The natural scientist often ignores his relationship to the social scientist, yet the social scientist studies the phenomena that give science its operational meaning. Science could not even come into existence until the phenomena studied by the social scientist had developed far enough to demand science as a social habit for its expression. Some scientists believe that the interactive relationships between human nature and social organization are not even data to be studied. They claim that it is not a concern of theirs if science is used for the destruction of life and property. Their only function is discovery, but this is not possible except where the interactive relationship between human nature and social organization permits this activity. After the present war, there may be a drive to stop scientific discovery unless its social nature is understood.

If the scientist is interested in freedom of inquiry, concerned with freedom of experimental verification, anxious about freedom for full publication, then he can not afford to ignore the interactive relationship between human nature and the social order, since it is here that the freedom of science will be established. The spirit of science, functionally speaking, is what it can become in the society where it exists. It is evident that the plan of life in some parts of the world involves the destruction of life and property, and there the spirit of science is in line with existing human nature. One of the chief interests of any scientist at the present time should be a concern over having the interactive relationship between human nature and social organization studied and understood. This is necessary for social control which will determine the nature of science.

Instead of saying that the interactive relationship between human nature and social organization is not a datum to study the scientist should demand that it be studied since it is in the control of this relationship that the nature of science will be determined.

The enemies of science call it a Frankenstein monster, but the monster is the interactive relationship between human nature and social organization. In its general form this Frankenstein monster existed before there was a well-developed social habit of science.

8. The Sociology of Science

It is possible to write the sociology of science just as it is feasible to present the sociology of marriage, crime or any other social habit through which human nature and social organization are made functional. Science is a social phenomenon in a general class with all other factors produced in the social process and the human nature of a scientist is the same general type of phenomenon as the human nature of a dictator. Both achieve their life organizations in the same way and both can express them through science. There is a social psychology of scientific thinking just as there is a social psychology of criminalistic or religious thinking. There is a social-psychological explanation for the scientist who does not see his relationship and that of science to all life, just as there is an explanation for the social variant who does not see his essential relationship to life.

It will be possible to save science after this World War only if its true social nature is recognized by every one concerned.

AMERICA'S AFRICAN ODYSSEY

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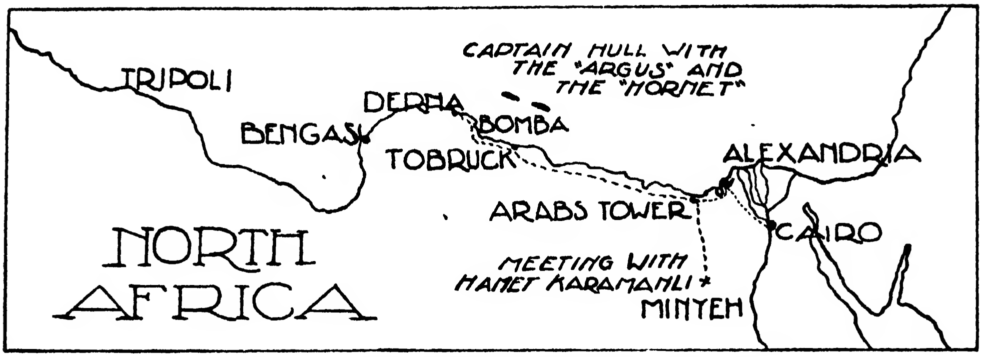
THE war has focused its great searchlight upon the North African shores of the Mediterranean. Libya, Siddi Barrani, Bardia, Tobruk, Derna, are counters quite passable in any conversation of to-day. We watch with intense interest the march and counter-march of the British, Italian and German armies along this narrow strip of coastline. So did Americans of more than a century ago concentrate their attention on this same North African shore; for along it was enacted a thrilling incident in American history. It was along this coastline that General William Eaton led a motley army of Americans, Italians, Greeks and Arabs across this same desert route with the object of rescuing some three hundred American officers and sailors held captive by Yusuf Bashaw, the Dey of Tripoli.

General William Eaton, the hero of this forgotten episode in our history, had served in the American army with distinction, but in 1801 retired to take an appointment as United States consul at Tunis. Then Tunis was one of the small states strung along the African coast of the Mediterranean, which existed solely by pirating the vessels of the Christian nations and by selling their crews into slavery throughout the Mohammedan world. These states were collectively known as the Barbary states, and it is to our everlasting honor that we, the youngest and almost the weakest of the nations which traded in the Mediterranean, were the first to attempt to clean out this nest of pirates and slavers. Out of our wars with the Barbary states was born our navy. Nearly every one of those naval commanders whose exploits fill the pages of our early history received his baptism of war in raids against Tripoli, Tunis and Algiers. It was in these waters that Stephen Decatur, John Rodgers, David Porter, Oliver Perry and a host of others won their first fame.

In 1801, the Bashaw of Tripoli, dissatisfied with the amount of tribute we were willing to pay him to refrain from molesting our ships, declared war upon us. President Jefferson dispatched a strong squadron to the Mediterranean to blockade the shores of Tripoli, but, despite these measures, the Bashaw's galleys continued to put to sea and to capture American vessels and enslave their crews. What was of much greater misfortune was that one of our largest naval vessels, the frigate, *Philadelphia,* in pursuing a Tripolitan galley too near the coast, ran ashore and, before she could be floated, was captured with her entire complement of officers and crew, numbering some three hundred men. These men were immediately thrown into the most horrible slavery, and it now became imperative for the American squadron to capture the city of Tripoli and thus release their comrades. This, then, was the setting which provided General Eaton with his opportunity to win undying fame in our history and the gratitude of his countrymen. In the end he won neither. Nevertheless, he conceived and carried through a project which played a determining part in bringing the Bashaw of Tripoli to make peace with the United States and to release the three hundred American sailors he held as captives in his dungeons.

Eaton landed in Cairo, the capital of the then Turkish province of Egypt, in December, 1804. His purpose was to put



MAP SHOWING GENERAL EATON'S ROUTE

into execution a project he had been long nursing in his mind. This project had for its object nothing less than to raise a small force of Arabs and whatever Christians he could induce to follow him and with this force to march across the Libyan desert lying between Egypt and Tripoli and to attack and capture Tripoli from the rear. President Jefferson had granted him some twenty thousand dollars to carry out this project and Eaton had received the rather vague promise that he would be supported as he advanced along the coast by one or two small vessels to be detached from the American squadron. His instructions were so vague that he likened himself to the Spartan warrior who, when asked by the King of Persia whether he came on public or private business, replied, "If successful, for the public; if unsuccessful, for myself." Eaton had induced to follow him in this adventure three officers from the American squadron and six marines. To this small force he subsequently was able to add a young Englishman, an Italian physician and a retired Tyrolese colonel of artillery. Around this nucleus he hoped to gather a body of Arabs which would be augmented as he successfully advanced along the coast towards Tripoli.

Eaton's scheme was not altogether a mad one, for he placed most of his hopes in the fact that the Bashaw of Tripoli was a much-hated usurper who had killed one brother and driven another into exile in order to seize the throne. Eaton had come to Egypt with the specific purpose of seeking out the rightful ruler of Tripoli, Hamet Karamanli, the exiled brother of the usurper. Eaton believed that, if he could find this Hamet and induce him to march across the desert, many Arab chiefs would flock to Hamet's standard, and the success of the venture would be assured. The first problem, therefore, was to find Hamet Karamanli.

When Eaton landed in Cairo, he found that the country was disturbed by one of the periodic revolts of the slaves or Malemukes against their Turkish masters. What was his dismay, however, to find that Hamet, having no other means of subsistence, had thrown in his lot with the Malemukes and was now attached to one of their chiefs, about one hundred and ninety miles inland from Cairo. Nothing daunted, Eaton, who was a master of flattery, induced the Turkish governor of Egypt to issue a firman granting Hamet a safe conduct out of Egypt. The governor probably issued this order with his tongue in his cheek, for he surmised that as soon as the Malemukes found out that Hamet was going to desert their cause, they would quickly kill him. Eaton found that there was no other way to get Hamet than to go into the desert interior and literally kid-

nap him away from the Malemukes. This was a perilous undertaking, as the country was filled with roving bands of robbers who would not hesitate an instant to rob and kill a party of foreigners. Nevertheless, Eaton, accompanied by some of his American companions, started into the desert in search of Hamet. After having proceeded for some seventy miles they were detained by a body of Turkish troops, but Eaton by flattery and bribery won over the Turkish commander and induced him to send an Arab chief to the Malemuke camp for Hamet. In the meantime Eaton and his companions, although hospitably entertained by the Turkish commander, realized that they were under arrest and that if the messenger sent to get Hamet did not return with him, they would very likely be hanged as English spies. The French consul at Alexandria had been busy spreading rumors that they were English officers sent to spy out the country and that the story about Hamet was merely a fiction designed to cover their real purpose. Fortunately, after several days, the messenger returned with Hamet, thus convincing the Turkish officer of the truth of their story. Eaton had little difficulty in inducing Hamet to fall in with his plans, and a rendezvous was appointed at the coast where the expedition was to gather.

After many delays, due chiefly to the fact that Eaton had entrusted most of his funds to one of the party for the purpose of purchasing the necessary supplies and that this individual had embezzled or misapplied most of the funds, the small army, on March 3, 1805, started its long march along the coast. Its immediate object was to capture the city of Derna, some six hundred miles west from Alexandria. After this Bengasi was to be taken, thus opening the way to an attack on the city of Tripoli. The company, as it finally was constituted, consisted of General Eaton in command, assisted by three American officers and six American marines, a company of twenty-five cannoniers, mostly Italians, and a company of twenty-eight Greeks. The rest of the force was made up of several Arab chiefs and about a hundred of their followers. Their armaments consisted of one field piece, supplemented by fifty or so muskets. The loyalty of the Arab chiefs was thoroughly undependable, and during the march across the desert, they were continually deserting and then rejoining the little army. A hundred and seven camels and a few donkeys with their drivers were hired to carry the baggage and supplies.

Before starting on the march, Eaton drew up a regular treaty between Hamet Karamanli, as rightful ruler of Tripoli, and the United States. In this treaty he promised the aid of the United States in replacing Hamet upon the throne, while Hamet promised to release all American captives held by his brother and to carry on peaceful relations with the United States thereafter. A curious feature of this treaty was that Eaton required Hamet to assign to the United States the annual tribute paid to Tripoli by Sweden, Holland and Denmark. This was for the purpose of recompensing the United States for the expense incurred in restoring Hamet to the throne.

In the first few days, the impromptu army made good progress, averaging about twenty-five miles a day. But there soon began a continuous series of difficulties which would have discouraged almost any one else. Eaton, however, remained calm throughout the journey across the desert and never once seems to have entertained the thought of giving up the expedition. On March 10, the camel drivers and footmen revolted, demanding more pay before they would move on another mile. Eaton partially met their monetary demands, but succeeded more by fair promises in inducing

them to go on. Such incidents as this became a matter of regular occurrence, and, more than once, the camel drivers departed with their camels, leaving Eaton and his companions stranded in the middle of the desert. However, by extravagant promises, he would get them to return and the march would be resumed.

Even rumors of good fortune endangered the lives of the small party of Christians. On March 13th, a messenger arrived from Derna with the report that the people of the city had revolted and caused the governor to take refuge in his castle. Afterwards, this rumor proved to be false, but, such was the excitement of the Arabs over this news that they immediately began to celebrate by riding their horses wildly around and shooting their guns into the air. This in turn almost brought disaster on the company of Greeks and Italians.

As Eaton notes in his diary, "In consequence of the good news, feats of horsemanship and a feu de joie were exhibited in front of the Bashaw (Hamet) by his people. Our foot Arabs, who were in the rear with the baggage, apprehending we were attacked by the wild Arabs of the desert, attempted to disarm and put to death the Christians who escorted the caravan. They were prevented by an Arab with some consideration among them."

By March 18th, Eaton's supply of cash had so dwindled that he was forced to borrow money from his officers and men in order to pay the camel drivers to carry them on further. Furthermore, due to the thievery of the Arabs, their supply of food began to disappear at an alarming rate, so that they were soon reduced to hard bread and rice. This brought on a real crisis, for on April 8th, the Arabs mutinied and refused to go further unless new supplies were received from Bomba from the American war vessel that had been detailed to meet Eaton there. The Arabs drew off in a body and began to prepare to charge the supply tent. The Christians lined up before it and were able to resist the first onslaught of the Arabs, who now withdrew a short distance.

Eaton has left a vivid picture of the whole incident in his diary. He says:

Discovering an intention among the Arabs to seize our provisions, I beat to arms. My Christians formed a line in front of the magazine tent. Each party held an opposite position for the space of an hour. The Bashaw dismounted and pitched his tent. Supposing the tumult tranquillized I ordered the troops to pass the manual exercise, according to our daily practice. In an instant, the Arabs took alarm; remounted and exclaimed, "The Christians are preparing to fire on us." The Bashaw mounted and put himself at their head, apparently impressed by the same apprehension. A body of about two hundred advanced full charge upon our people, who stood their ground motionless. The enemy withdrew to a small distance, singled out the officers, and with deliberate aim cried "fire!" Some of the Bashaw's officers exclaimed, "for God's sake do not fire." Mr. O'Bannon, Mr. Peck and young Farquhar, stood firmly by me. Salem Aga, captain of cannoniers, his lieutenants, and also the Greek officers, remained steadfast and at their posts. The others were agitated and in fact abandoned us. I advanced towards the Bashaw and cautioned him against giving countenance to a desperate act. At once a column of muskets were aimed at my breast. The Bashaw was distracted. A universal clamor drowned my voice. I waved my hand as a signal for attention. At this critical moment some of the Bashaw's officers and sundry Arab chiefs rode between us with drawn sabres and repelled the mutineers. The fracas nearly resumed its rage when I took the Bashaw by the arm; led him from the crowd and asked him if he knew his own interests and his friends. He relented and called me his friend and protector; said he was too soon heated and followed me into my tent, giving orders to his Arabs to disperse.

On April 5th, the half-starved company reached the Gulf of Bomba, the site of the present Italian base of Tobruk. Eaton was greatly distressed not to find there Captain Hull and the *Argus*, which was to bring him supplies and money. This did not keep him from remarking in his diary on the fine situation of

Tobruk, and he predicts that some day it would make a fine harbor and roadstead. That night he lighted fires on the surrounding mountain peaks, with the result that the next morning Captain Hull appeared in the Bay with the *Argus* and the *Hornet*. Supplies were soon conveyed ashore, and Eaton and his motley following now resumed the march towards the city of Derna. They found the city well defended by the Governor and also learned that the usurper, Yusuf Bashaw, had sent reinforcements which were encamped on the western side of the town. Fortunately for Eaton the day after their arrival outside of Derna, three vessels from the American squadron, the *Argus*, *Nautilus* and *Hornet*, arrived off the town. Eaton now sent a demand to the Governor that he surrender, but the Governor's only reply was the laconic message, "My head or yours." On the 26th, the attack was opened. Eaton and his Christians posted themselves on a prominent height overlooking the town, but they were soon opposed by a considerable body of Arabs. What was worse was that their one gun temporarily was put out of commission by having the rammer shot away. Eaton also received a nasty wound in the wrist.

In this crisis Eaton reports that "I perceived that a charge would be our *dernier* and only resort. We rushed forward to a host of savages more than ten to our one. They fled. . . ." Within three hours the city was in the hands of Eaton and his forces, but its capture had cost the lives of two of his marines. Among the Greek foot soldiers fourteen were killed and wounded, of whom he remarks "in this engagement they supported their ancient character." It was in the hour of victory that Eaton almost disgraced himself in the eyes of both his Arab supporters and his Arab foes. The Governor, seeing the city lost, had taken refuge in the harem of one of his sheiks. This Sheik favored Hamet but, the Governor having taken refuge in his house, it became his sacred duty to protect him and to aid him to escape. Eaton committed the error of urging that the house be stormed and the Governor forcibly arrested, not realizing the sacredness of the harem as a place of refuge among the Mohammedans. All demurred, and during that same night the Governor, aided by his host, succeeded in escaping. The next day this same Sheik came out openly in favor of Hamet Bashaw. In offering his aid he took the opportunity to reproach Hamet for even listening to Eaton's proposal to invade the sanctity of the harem. As recorded by Eaton, the Sheik made a very noble speech. He said:

> I have this day given you, I trust, an unequivocal demonstration of my personal attachment and fidelity. I ought to say to you that you have not merited it. You would have yielded to the instances of the Christian general in violating the hospitality of my house and or degrading my honor and my name. You should recollect that not quite two years ago you were saved in this same asylum, and secured your escape by the same hospitality from the vengeance of the very same Bey. Had fortunes of this day gone against you I should have suppressed these sentiments of reproach. . . .

Derna having been captured, Eaton now wanted to push on to Bengasi and Tripoli and with the aid of the American squadron reduce the capital of Yusuf Bashaw, thus effecting the rescue of the three hundred American sailors held in his prisons. But Commodore Barron, in command of the squadron, disagreed with this plan. He felt that his instructions left him no other alternative than to make peace with Yusuf Bashaw as soon as the latter showed signs of wanting to come to terms. The fall of Derna had brought Yusuf to this frame of mind. In vain Eaton pleaded that the United States was committed to aid Hamet in regaining his throne and that if we now deserted him, his brother would take a terrible vengeance upon him and upon the people of Derna for having allowed their

city to be captured. Barron, however, was more concerned with the immediate release of the crew of the *Philadelphia*, and he entertained some fear that if Eaton were permitted to march against Tripoli, the lives of these captives might be endangered. On June 11th, the *Constellation* arrived from Tripoli with the news that peace had been concluded and ordered Eaton to evacuate Derna immediately. Eaton realized that if this news were to become known among the people of Derna, they, in their rage and despair at being deserted, would immediately turn upon him and his Greek and Italian followers and massacre them. He therefore, spread the report that the *Constellation* brought reinforcements and supplies and that the march to Tripoli was to be resumed. That night he smuggled his Christian followers aboard the *Constellation* and then he prepared to leave the city to the vengeance of the followers of Yusuf Bashaw. He says of this moment, "When all were securely off, I stepped into a small boat which I had retained for this purpose, and had just time to save my distance when the shore, our camp and the battery were crowded with the distracted soldiery and populace." Bitter indeed was his thought as he watched the city fade astern. He believed that he had been led to trick Hamet and his followers into furthering the interests of the United States and that once those interests had been secured, Hamet and the city of Derna had been betrayed to the cruelty of Yusuf Bashaw.

General Eaton returned shortly after these events to the United States, where he was received as a conquering hero. The populace believed that his march across the desert had been instrumental in securing the release of the three hundred sailors of the *Philadelphia*. The Administration and Congress thought differently. A motion to grant him a medal was defeated by Congress, and his financial accounts became a subject for Congressional inquiry. He had spent ten thousand dollars more than Jefferson had allotted him, about thirty thousand dollars in all. His accounts were none too carefully kept, and this became of more concern to Congress than the very evident fact that he had accomplished single-handed a most remarkable feat which had greatly aided the United States to bring to an end the war with the Bashaw of Tripoli and to secure the release of the *Philadelphia* captives. Thereafter American commerce in the Mediterranean was free from molestation. Massachusetts, the state which had suffered most from the depredations of the Barbary corsairs, was more liberal in her treatment of this unique hero. He was given a farm of ten thousand acres by the State Legislature. He died there in 1811 at the age of forty-seven, his health broken by his arduous adventures and his spirit broken by the ingratitude of Congress.

BOOKS ON SCIENCE FOR LAYMEN

THE LIFE OF WILLIAM HENRY WELCH[1]

BECAUSE of Dr. Welch's lack of interest in a biography of himself we were in doubt as to which of those we had considered for this task might seem best to him, until by chance, in discussing a biographical sketch of his father, I mentioned this list and at once he chose Flexner, so that next day our advisory board formally asked Dr. Flexner to undertake it. This was shortly before Dr. Welch's death, and whatever the affection and enthusiasm with which it was undertaken it is obvious that this was an enormous task, for there were so many letters and documents to be analyzed, so many acquaintances and so many huge institutions to be consulted, that to put together a continuous story of his life and of all his accomplishments was obviously the work of years.

But we feel that it could not have been more successful. With his long close association with Dr. Welch and with interests quite corresponding with his own, not only in pathology but in the organization of great institutions, no one could have had a better background for the work.

The description of the family, of his boyhood life and education and his early years in New York with his growing interest in pathology and in the teaching of small groups of students is vividly told, and the conflict in his own mind, but especially among his friends, as to his acceptance of the place at the Johns Hopkins University is finally cleared.

Throughout the remainder of the book there is presented an admirable revelation of his personality, which was not merely impressive because of his great ability and his extreme erudition, but lovable because of his human sympathies. As the teacher of pathology and bacteriology, with his never to be forgotten lectures and his personal contacts with his pupils, he will ever be remembered. But with the public and all those in authority it was the same, and his wisdom in any project was awaited with complete confidence.

His numerous visits to European countries, where he spent much time in the laboratories of the most famous workers, impressed them with the same high opinion of his extraordinary intelligence and ability, and they too were, for always, attached to him as a man.

Consequently throughout his life, after he became established in the developing of Johns Hopkins University, he was called upon for such active participation in the proceedings of many societies, and in the organization of so many scientific undertakings that his life was laborious.

As an active investigator in his own subject he did contribute a number of scientific results, among which perhaps the best was the discovery of the gas bacillus. But his papers on more general subjects, such as fever, infection of wounds, adaptation in pathological processes, etc., are very impressive.

In this biography it is made especially evident that his genius was endowed with the ability to realize and foresee the importance of certain fields in medicine in relation to the welfare of the nation or of the world, and to outline the organization of the institutes for this purpose, and even to select those who should form their staff of workers, and especially one who should be director. So successful was he in presenting such a plan, that with the aid of his fascinating personality he acquired such enormous gifts of money that one after another of these plans was thoroughly established.

[1] *William Henry Welch and the Heroic Age of American Medicine.* Simon and James Thomas Flexner. Illustrated. x + 539 pp. $3.75. 1941. Viking Press.

The description of his numerous journeys, even to China and other countries, bears with it the same atmosphere of eager reception of him by people anywhere in the world, for his character was famous.

On the whole it seems that this presents an extremely satisfactory description of Dr. Welch—not only in the details of his whole life, but in the clear picture of himself and of his extraordinary accomplishments.

W. G. McCallum

MATHEMATICS MADE INTERESTING[1]

In the past decade a number of mathematical books have broken with the drier-than-dust tradition in an attempt to show students and laymen that mathematics did not end with Euclid, or even with Descartes and Newton. Professor Merriman's book is of this kind and, in the reviewer's opinion, should accomplish the end for which it was designed.

Although the topics presented are those of the usual college course for nonspecialists, the treatment is not stereotyped. Frequent mention of post-Newtonian contributions to quite elementary mathematics enlivens the presentation and should stimulate further interest. The outlook is broadly historical, setting mathematics in its just perspective in the general development of culture. The student who goes through this course may not acquire the dexterity necessary to reduce an algebraic fraction as complicated as a Chinese pagoda to relative flatness, and he may finish without the technique demanded for eviscerating a moderately fantastic definite integral. But he will have learned that mathematics did not petrify 2,000 or 300 years ago.

To give some idea of the contents, the following are a few of the thirteen chapter headings: "The Fountainhead"—number; "Algebraic Counterpoint"—algebra, but not as in the texts for the College Entrance Board examinations, thank God (and the author); "Euclid Alone"—incidentally querying Edna St. Vincent Millay's "Euclid alone has looked on Beauty bare"; "Declaration of Independence"—functionality; "Eventually, and Forever After"—limits and continuity; "Period Piece"—goniometry; and last, "Peak in Darien," which conducts the reader to a high place where he may be as lonely as he likes, and from which he can look out over the expanse of mathematics.

An appendix of 67 pages contains numerous bibliographical notes, problems of an interesting kind and amplifications of the text. Any student of college mathematics should find much to interest him in this unusual text, even if used only for collateral reading.

E. T. Bell

[1] *To Discover Mathematics.* Gaylord M. Merriman. xi + 435 pp. Illustrated. $3.00. January, 1942. John Wiley and Sons, Inc.

ORNITHOLOGISTS OF THE UNITED STATES ARMY MEDICAL CORPS[1]

A book bearing the title "Ornithologists of the United States Army Medical Corps" may well strike one as something strange. Coming off the press just now, in the midst of a great war, it may seem like a breath from a past age—when even warfare was less intensive and army doctors had time and opportunity to study and collect birds while engaged in their professional duties. However, when it is recalled that the army was the great exploring, as well as the military, branch of the government during the opening up of what are now our western states, it is less surprising to see what great contributions to all fields of descriptive science were made by its more gifted personnel. Thirty-six army medical men are given due biographical treatment and grateful evaluation for their ornithological work in the present vol-

[1] *Ornithologists of the United States Army Corps.* Edgar Erskine Hume. Illustrated. xxv + 583 pp. $5.00. 1941. Johns Hopkins University Press.

ume. Only regular army men who were ornithologists are discussed; no ornithologists, who, by virtue of a war, were temporarily in army medical units, are included. While a number of the scientifically more outstanding of these men have been made the subjects of biographical memoirs before, their biographers lacked the military data as to their careers and were forced to treat them as they would have treated civilian naturalists. It was understood, of course, that it was the fact that they were in the army that gave them their opportunities for travel and collecting in out-of-the-way places, but each man was treated as an individual case, and the role of the army as an active agent in natural history exploration was never sufficiently stressed.

Inasmuch as these army trips were official governmental assignments, the materials collected naturally gravitated to the United States National Museum or, before its inception, to its parent institution, the Smithsonian Institution. Here the accumulations from these field activities were carefully studied and the results given adequate publication either in Smithsonian publications or in those of the War Department. In this way, the work of the army medical naturalists was not only utilized to the full but was given world-wide continuing usefulness in generously distributed publications. It is, therefore, a happy coincidence that the foreword to this book is written by Dr. Alexander Wetmore, assistant secretary of the Smithsonian Institution and director of the National Museum.

Students of American birds, long familiar with the names of such men as Bendire, Cooper, Coues, Heermann, Mearns, Shufeldt and Xantus, will find much of interest in this book, much that is new to them, and will learn of the lives and work of other ornithologists less well known to them. Army men may learn with surprise and with no small satisfaction of the contributions to even a limited, specialized branch of science, made by their medical colleagues. The book is an important contribution to the history of natural science in America.

HERBERT FRIEDMANN

SCIENCE FOR CHILDREN[1]

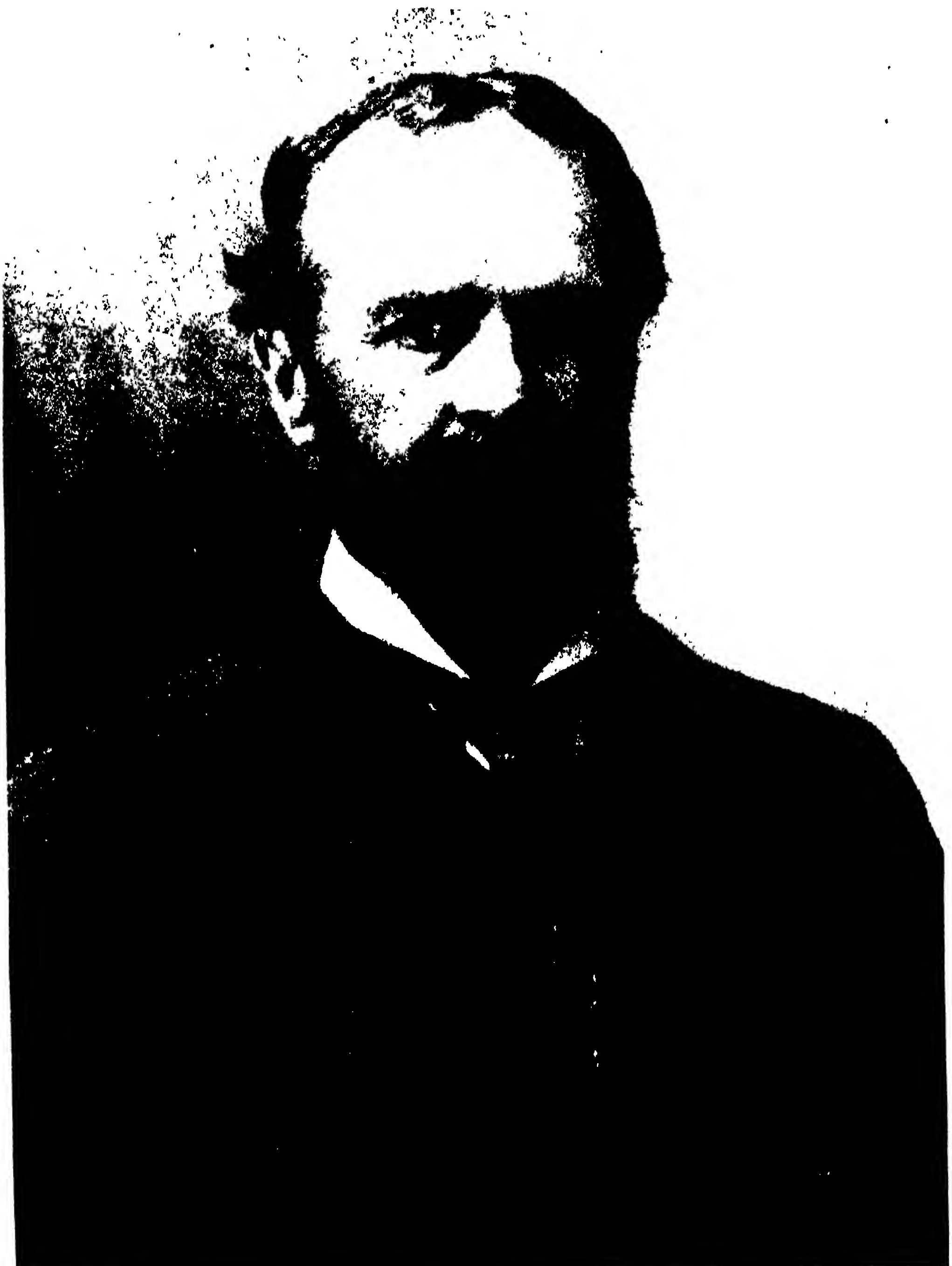
BERTHA STEVENS is a wise teacher. This book follows her "Child and Universe" and "Thoreau, Reporter of the Universe" and, like them, is addressed to parents and teachers. It is a beautiful model for the instruction of young children and for answering their questions as they explore their world. It is exquisite in its poetic and imaginative values; it is realistic in beginning, as children do, with concrete objects and in stimulating and answering the bouquet of questions that burst into bloom whenever a new experience enters the mind of a child.

The subjects of the ten chapters are mundane enough: a star, a magnet, a salt crystal, a dew-drop, a lima bean, a petunia, a tree, a snail shell, a goldfish and a human hand. Each is illustrated with beautiful photographs and with clear, clever, line drawings. Each also has a list of references for further reading—in case the parent or the teacher himself becomes engrossed in the study. Teachers of science for young children should by all means study Miss Stevens's appreciation of the use of poetry, art, embroidered imagery and the sweep of imagination that each of these objects brings to the child, though seldom to the specialized teacher. But even more the non-scientific teacher and the unscientific parent can learn from Miss Stevens the fascination of nature and the beauty of concept and natural law which are inherent in these familiar objects. Surely parents of young children should read Miss Stevens and all those who have not learned from Shakespeare to:

> Find tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything.

GERALD WENDT

[1] *How Miracles Abound.* Bertha Stevens. Illustrated. 200 pp. $2.50. 1941. John Day.



WILLIAM JAMES, 1842–1910

THE PROGRESS OF SCIENCE

WILLIAM JAMES, 1842–1910

It is the fortune of some thinkers to modify so radically the color of their intellectual environment that many of their hardest-won ideas appear like commonplaces to succeeding generations. In many respects this has been the fate of William James, the centenary of whose birth is being celebrated this year. It is true that not all the positions for which he fought in psychology and philosophy have become widely accepted; nor did he leave behind him a sizable following of disciples who subscribed to the essential details of his thought. But the larger features of his work—its voluntaristic naturalism and empiricism, its distrust of dogmatic claims to final truth, whether in science, philosophy or religion, and its emphasis upon the novelties and contingencies which characterize the operations of nature—have been intimately absorbed into our own modes of thought; we can appreciate the innovations they represented only by contrasting the quality of our own intellectual atmosphere with that of James's generation.

James's most distinguished and substantial contributions were made to psychology. He came to the subject when the dominant point of view was an atomistic associationalism colored by remnants of the classical faculty psychology, and when instruction in it in this country was ancillary to buttressing religious and moral dogmas against the encroachments of natural science. James was rapidly convinced of the sterility of the customary introspective analyses, became impressed by the work of Helmholtz and Wundt in physiological and experimental psychology, and early in his career desired for psychology the status of a natural science. He was the first to teach physiological psychology in the United States, and stimulated the establishment of psychological laboratories in various parts of the country; but he never regarded psychology as simply a branch of physiology, his own experimental work was relatively insignificant, and in the end he came to distrust "brass instrument" psychology as a blind alley which would never lead to the achievement of an integral and illuminating science of man. What James envisaged was a psychology assimilated to biology, which would exhibit man's place in nature and explain mental phenomena in genuinely causal terms, and which would thus provide, among other things, the instruments for controlling various mental disorders. He was conscious that this ideal was far from being realized, and upon completing his "Principles of Psychology" (in 1890) he remarked that "psychology is like physics before Galileo's time—not a single *elementary* law yet caught a glimpse of." Nevertheless, his great treatise blazed a path in the desired direction, even though it retained some of the preconceptions of subjectivistic psychology. It adopted the Darwinian idea of the mind as an instrument in the body's evolutionary interaction with the environment; it rejected, accordingly, the Spencerian conception of the mind as the passive recipient of external stimuli, and argued for its intermediary, teleological function with respect to the overt action of the body. It dismissed as gratuitous the introduction of substantial, nonempirical agents (such as the "transcendental ego") to account for the obvious unity of mental life; and it attempted to explain this unity both in terms of the mechanism of organic behavior and in terms of the cumulative continuity of the stream of direct experience. James thus directed psychology toward the study of the activities and experiences of the entire organism functioning in an environment, and away from its traditionally exclusive concern with atomized, isolated and subjective contents of a disembodied mind. Although he never quite transcended in a coherent and unambiguous way his ini-

tially postulated dualism between states of mind as psychic existences on the one hand and the objective order of physico-biological mechanisms on the other—indeed, he came to accept a form of the interaction theory of their relation—James laid the foundations for a behavioristic functionalism in psychology, and anticipated important features of other contemporary movements in psychology as well.

While James's intense preoccupation with a considered philosophic outlook upon things is exhibited on almost every page of his explicitly psychological writings, he never achieved a comprehensive philosophy comparable in its sweep and coherence with his treatise on psychology. His numerous books and essays on philosophical themes are fragmentary and suggestive preludes to the systematic work he planned to write but did not live to begin, and the pluralistic pantheism at which he finally arrived was never more than sketched out by him. James's concern with metaphysics was rooted in his profoundly personal religious needs and in his desire to find a cosmic ground for significant moral endeavor. But whatever their psychological sources, his philosophical essays were fructified and served as instruments of clarification by his unusually sensitive recognition of the irreducible variety, the precarious stability and the unique individuality of existential affairs. In spite of his tender concern for the moral values of mystic religious experiences and his espousal of theism, James stimulated the development of a biological, empirical naturalism—a naturalism comprehensive enough to admit the dynamic primacy of men's wills and desires, but also sufficiently responsive to empirical findings not to accept at their face value the claims of the dominant institutional and philosophic religious systems. He thus noted the function of religious beliefs in the context of adjustment to the inclusive environment, while at the same time he regarded as pretentious shams the alleged demonstrations of religious truths which were advanced by the philosophies current in his day. He could find no warrant, either in experience or logic, for the conception of the universe as something integrated by necessary bonds and headed inevitably toward a fixed goal; but he could nevertheless define the conditions under which, in the interests of successful living, it is justifiable to embrace beliefs even when, as frequently happens in matters of vital issue, warranted knowledge is not available.

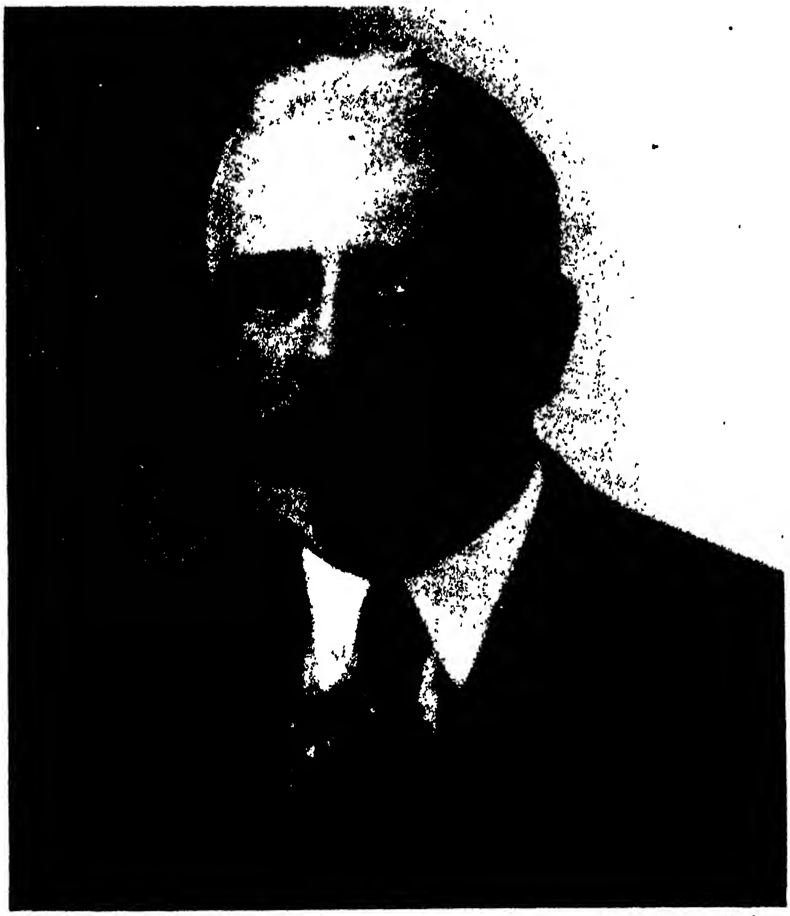
James's most distinctive contributions to philosophy are consequences of his vigorous individualism and pluralism. He championed pragmatism as a method for determining the significance of concepts in terms of their consequences for individual experience and practice and as a device for permitting the breezes of fresh experience to revivify ancient issues. In his application of the pragmatic maxim to the perennial problem of the nature of truth, for example, he underscored the instrumental rather than the reproductive character of thought, and he made evident the empirical and natural foundations of human knowledge. He found the notion of a monistic determinism, whether in physical nature or in human history, to be incongruous with the patent variety of existential determinations and with the actual role played by individuals in dynamic transactions; and while he had no systematic social philosophy, he was an individualistic liberal in his evaluation of contemporary affairs and maintained that moral activity would lack significance if individual intervention in natural processes made no difference in their eventual outcome. James was impressed by the magnitude or our ignorance and distrusted the authoritarianism of institutionalized science as well as religion. He was therefore unusually and perhaps even quixotically tolerant toward heterodoxy, and championed causes held in disrepute by the established professors of science. His

defense of psychical research, for example, was motivated as much by his opposition to the dogmatic apriorism which dismissed allegedly psychic phenomena as spurious without a proper examination, as by his conviction that something significant lay beneath the quackery of spiritualistic séances. James was undoubtedly hasty, impatient and incautious in much of his philosophizing, and his frequently ill-considered formulations led to serious misunderstandings and to irrational disavowals of the tools of critical intelligence. But because he communicated the freshness which comes from sailing courageously on the unfathomable ocean of experience, he brought relief from the stuffy dogmatisms of less-traveled folk and helped introduce new standards of intellectual forthrightness and honesty. Of James it may be said what he said of another: he was the knight-errant of the intellectual life.

ERNEST NAGEL

AWARD OF THE CHEMICAL INDUSTRY MEDAL FOR 1942 TO DR. HARRISON E. HOWE

HARRISON ESTILL HOWE, honored by the award of the Chemical Industry Medal for 1942, has for a score of years guided the destiny of *Industrial and*



Harris and Ewing

DR. HARRISON E. HOWE

Engineering Chemistry through a period of enormous fecundity of industrial research. The medal—given annually "to a person making a valuable application of chemical research" by the Society of Chemical Industry—will be presented to Dr. Howe on November 6. His function has been that of guide, philosopher and friend to industry on the one hand and to research on the other. To each he has interpreted the other in a way to foster mutual confidence and cooperation.

Editors generally content themselves with the printed word alone as their medium of expression and make for themselves a kind of secluded cloister behind their pages. That could never content Dr. Howe. His boundless humanity has required personal contacts, multitudes of them, to give it scope. Thus one finds him a member by appointment, *ex officio* or by special invitation of committees by the score. These duties for and to applied chemistry are so much a part of the man that he is constantly taking on new commissions. In all, his vigorous imagination, his kindly humanity and his huge capacity for work have combined to make him one of the best-loved and most respected figures in American chemistry to-day.

Primarily Dr. Howe's activities have been connected with the American Chemical Society, to which he has given much. But the National Research Council, Science Service and the Chemical Warfare Service too have drawn heavily upon him, as have many, many others.

As if his activities in and for chemistry and research were not enough, Dr. Howe has maintained as an active avocation a prominent and busy place in Rotary International. Always he is busy and always occupied with people.

Yet in spite of his outstanding collection of activities of many kinds (which he calls "goat feathers"), Dr. Howe seldom appears to hurry, never bustles, and always has time to do a good turn for any one who needs his help.

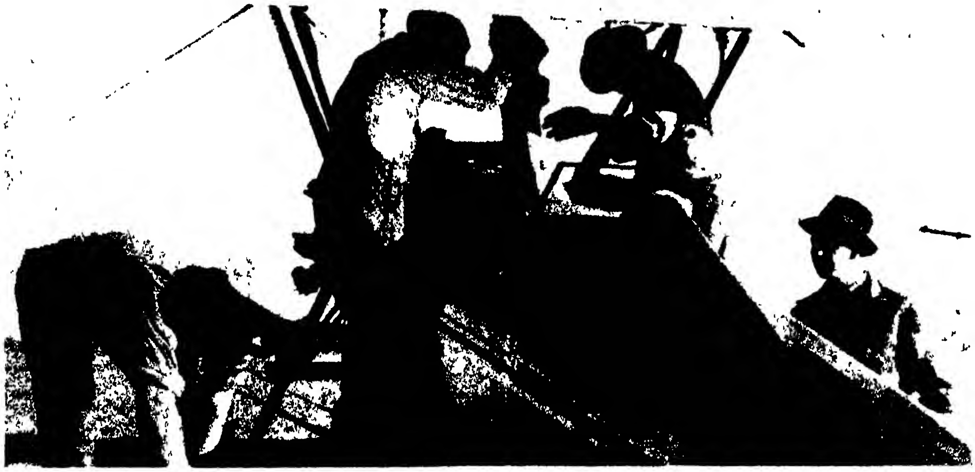
Summing up a career of such catholicity of interest and accomplishment is a task of major magnitude. Indeed, it is quite impossible to stop its progress long enough to get more than fleeting glimpses of its many ramifications. Clearly the outstanding achievements of the man and editor are to be found in the extraordinary development of the publications under his care. *Industrial and Engineering Chemistry* has grown to occupy under his guidance an outstanding place in the research literature of the world. It has been split into three principal parts, Industrial and Analytical Editions and *Chemical and Engineering News*, each of which is an outstanding publication in its own right and field. The American Chemical Society News Service has, under Dr. Howe's supervision, become a recognized agency for the general dissemination of news about chemistry and chemical industry to the public at large. The Technological Series of American Chemical Society Monographs has been built by him into a vital and growing library of chemical technology.

Any of these major achievements would merit recognition by a medal. The combination of these and innumerable lesser accomplishments by one man richly deserves the highest accolade.

D. H. Killeffer

CONTROL OF DESTRUCTIVE INSECTS BY AIRCRAFT

In the production and storage of food during times of peace certain practices and methods are used to reduce the larger losses caused by insect pests, while many of the smaller ones are not seriously regarded by the producer and dealer. When the more serious insect pests, such as grasshoppers, threaten the destruction of crops over large areas, organized and well-directed campaigns are required for their control. The gradual adaptation of such combat methods and the use of airplanes by the Bureau of Entomology and Plant Quar-



LOADING THE HOPPER OF A PLANE WITH BAIT

antine over a number of years have demonstrated that airplanes do effectively serve in reconnaissance for the pests, as well as for wholesale destruction of the insect invaders through applications of poisoned dusts and baits.

As early as 1919 airplanes were used, under the direction of W. D. Hunter, for locating fields of cotton in the areas recently infested by the pink bollworm and mosquito breeding areas that were otherwise concealed from view by wooded and swamp lands. These surveys were followed by use of aircraft in dusting wooded areas for the catalpa sphinx in 1921; by development of methods for dusting fields of cotton with calcium arsenate at Tallulah, Louisiana, for control of the boll weevil in 1922; and to a limited extent for applying paris green to the swampy breeding places of malaria-carrying mosquitoes. Control of mosquitoes by airplane was accomplished in Louisiana and South Carolina about twenty years ago, and recently the Tennessee Valley Authority applied 100,000 pounds of paris green to breeding places under its control. An oil and a liquid pyrethrum larvicide were also effectively applied to mosquito-infested marshes in New Jersey, but airplanes have not yet been used extensively in applying liquid sprays. It is likely that a reduction of weight load through the use of concentrated sprays may facilitate airplane use on mosquito-control projects.

An experimental airplane dusting of cotton at Tallulah with calcium arsenate in 1922 for the control of boll weevils resulted in an increase of 750 pounds of seed cotton per acre. It was estimated that a single plane manned by a pilot and two mechanics was capable of doing the work of 1,500 to 2,000 men with hand dusters on the ground. There was also a saving in the time required for applications when the fields were too muddy for operation of ground machines. By 1941 about 200 airplanes were engaged in dusting cotton and other crops, and during the year approximately 1½ million acres of cotton and several hundred thousand acres of vegetables were treated in this manner. Airplanes have also been used for seeding range lands and rice and for applying fertilizers. Owing to the need for trained pilots in military services, there has been some reduction in crop dusting.

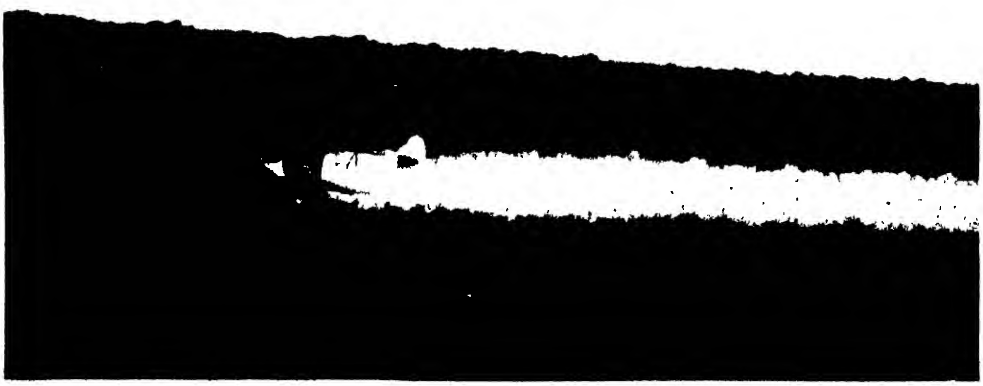
In 1939 commercial airplanes applied 2,609 tons of poisoned bran and sawdust bait to a total of about 260,000 acres of land in Montana for the control of grasshoppers. The applications were made after flights of the

DUSTING SHALLOW WATER FOR CONTROL OF MALARIA MOSQUITOES

lesser migratory grasshopper (*Melanoplus mexicanus mexicanus* (Sauss.)) to locations for resting and feeding upon growing crops were observed from airplanes. When the grasshoppers settled in new places, it was necessary to truck supplies of bait from mixing stations to improvised landing fields and to service the planes as rapidly as possible. The cost for mixing, handling and spreading the bait by airplane averaged $23.57 per ton, or about 24 cents per acre. Since this work was accomplished primarily in restricted areas where the adult hoppers were concentrated, the baiting protected the growing crops by poisoning the hoppers. Because the poisoning occurred before egg laying took place, the baiting also reduced infestations for the following year.

Another migratory grasshopper, *Dissosteira longipennis* (Thos.), which occurs in the southern portion of the Great Plains, has the habit of congregating for the purpose of laying eggs. From an airplane it was possible to detect the egg beds and to apply the poison baits effectively to these concentrations. It is estimated that about 90 per cent. of the adult populations of this species were poisoned in this manner, a considerable portion of the work being accomplished in rugged terrain that was not accessible by any other means.

In the Northwest, where Mormon crickets are a serious problem, the timely use of hand and power machinery



DUSTING FOR CONTROL OF THE BOLL WEEVIL ON COTTON

DUSTING FOR CONTROL OF THE WHITE-FRINGED BEETLE

for baiting and dusting crickets was effective in protecting crops. These methods did not prevent migrations of crickets each year from the higher elevations, and the uncontrolled areas in the mountains were too rugged for ground distribution. There was a distinct need for the control of newly hatched crickets in the early spring at or near the egg beds to prevent the formation of migrating bands which might invade the valleys and crop lands. In 1941 aircraft was successively used in locating these concentrations of crickets and destroying them by applying poisoned bait before they invaded the lowlands. The use of airplanes over much of the area reduced the costs to an average of 59 cents per acre as compared with $2.15 for the ground methods employed in 1938. The average cost per acre baited by airplane was 29.97 cents in 1941.

In baiting grasshoppers in the vicinity of crops in 1941, airplanes treated on an average 1,633 acres each day, while a ground crew operating a mechanical spreader averaged 91 acres. In other words, 1 airplane with a crew of 4 men accomplished as much work as 18 trucks and bait spreaders with a crew of 36 men, and since the purchase price of the spreaders and trucks amounted to about the same as that of the plane, there was no additional investment for equipment.

In 1942 more than two square miles of gypsy moth-infested woodlands in a rugged portion of Connecticut were treated by applying lead arsenate and fish oil in

AUTOGIRO DUSTING WOODLAND FOR INFESTATION OF THE GYPSY MOTH

a dual jet from an autogiro. The cost of such treatment was materially less than would have been involved in the use of standard types of apparatus. The success obtained with this method gives promise that it may be found satisfactory for combating various other pests.

The use of airplanes for scouting, dusting and baiting for control of destructive insects may now be considered an important factor in the protection of food and fiber crops by averting the losses caused by insects, and by distinctly conserving manpower for the big job of winning the war and feeding the hungry.

W. E. DOVE

THE SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATIONS

A TENTH Summer Conference on Spectroscopy and Its Applications was held at the Massachusetts Institute of Technology on July 20 to 22, 1942, under the joint auspices of the Optical Society of America and the Institute.

In view of the difficulties of transportation during the emergency, and the fact that most spectrographic analysts are heavily occupied with war work, it had been considered doubtful whether the usual conference should be held this summer. In order to determine the probable attendance and the number of papers likely to be presented at such a conference, postcard ballots had been sent out early in the year. The response to these indicated that a conference would be well attended if held. The attendance turned out to be 302, an excellent growth from the 65 who had registered at the first conference in 1933. That the conference was so well attended is probably due to the fact that spectrographic methods of analysis are of increased importance now in many war industries.

In his welcoming remarks, the chairman took the occasion to sum up the progress in spectrographic analysis which had been made during the preceding decade, as indicated by a detailed analysis of the categories of paper presented at the ten conferences.

Probably the most important trend noted was the increase in interest in the application of spectrographic methods to problems of chemical and metallurgical analysis in industry. Of the three hundred papers which had been presented at the ten conferences, most in the early sessions dealt with pure spectroscopy or with applications of spectroscopy to biology, whereas in later years the emphasis was on applications in metallurgy and to industry in general. The tabular analysis showed: Papers dealing with emission analysis—64; with absorption spectro-photometry—28; with improvements in the techniques of photography—9. Forty papers were concerned primarily with the improvement of spectrographic apparatus. The remaining papers dealt with applications of spectroscopy to various scientific fields—8 were concerned with astronomy, 68 with biology, 25 with chemistry, 26 with metallurgy and 33 with physics.

Of especial interest was the increased use of diffraction gratings, particularly in industrial laboratories. At the first conference the statement that grating spectrographs should be found useful in industry had been greeted with much skepticism. At the tenth, two manufacturers presented descriptions of new commercial grating spectrographs constructed on the Wadsworth principle.

Notable also was the increase in the precision of spectrographic methods of qualitative analysis which ten years have brought about. At the first conference the results obtained by emission analytical methods could be expected usually to be correct to within ± 10 per

cent. of the concentration of material or, in exceptional cases where great care was taken, ± 5 per cent. Even this degree of precision was worthwhile, since by spectrographic methods it was possible to determine minute concentrations of impurities in a sample without the bother of chemical preparation. By 1942, however, precision had been increased so much that routine analyses are being carried out with a precision of ± 3 per cent., and several workers reported results at the conference which showed an internal consistency and check with carefully prepared standards to within ± 0.7 per cent. of the amount of material present, whether 5 per cent. or 0.0005 per cent. These results are to be compared with results obtained with ordinary wet chemical methods of analysis which are likely to be precise within ± 2 per cent. for concentrations of 1 per cent. or greater when a sufficiently large sample is available, and to errors as great as 100 per cent. when concentrations are still a thousand times the minimum detectable with the spectrograph.

The tenor of the introduction by the chairman was carried on by Dr. W. F. Meggers, of the National Bureau of Standards, who spoke on "Ten Years' Progress in Spectro-chemical Analysis," and by Dr. Keivin Burns, of the University of Pittsburgh, who spoke on "Spectroscopy in World War I."

In view of the dual nature of the conference, the arrangement of meetings was somewhat different than that of previous occasions. During the first day and a half 16 papers were given which dealt primarily with spectrographic analysis of materials. On the second afternoon a Symposium on Invited Papers on Fluorescence and Phosphorescence was held. This consisted of four papers, ranging from "The Theory of Luminescent Materials," by Professor F. Seitz, of the University of Pennsylvania, through "Fluorescent and Phosphorescent Lamps," by E. W. Beggs, of the Westinghouse Electric and Manufacturing Company, and "Fluorescent and Phosphorescent Pigments and Coatings," by G. F. A. Stutz, of the New Jersey Zinc Company, to "Cathodoluminescent Materials," by H. W. Leverenz, of the RCA Manufacturing Company.

On the third day regular sessions of The Optical Society of America were held, the papers given in the morning dealing with general problems of optics, while those in the afternoon dealt primarily with spectrographic applications.

At the tenth conference it was apparent that it and its nine predecessors had been held during the period of most rapid growth in the application of spectrographic methods of analysis to problems in all the natural sciences, and in most of the biological, metallurgical and agricultural industries.

George R. Harrison

THE NEW AUDUBON BIRD HALL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

After four years of planning and work, the staff of the Academy of Natural Sciences of Philadelphia is being rewarded on October 7 when the new Bird Hall, named for John James Audubon, will be opened with a reception to members. The next day the hall will be open to the public and will be one of the centers of attention when the American Ornithologists' Union convenes in Philadelphia later in the month.

The Bird Hall, situated on the third floor of the academy's building at Nineteenth and the Parkway, replaces a bird hall which was fashioned in the manner of the nineties. In three great sections from which natural light is excluded, the birds of the world are shown in natural

positions against backgrounds representing their habitats. These backgrounds have been painted by Virginia Campbell, the staff artist, under the direction of R. Meyer deSchauensee, curator of birds, and Harold T. Green, curator of exhibits. Frederick Stoll is responsible for the taxidermy.

The same characteristic energy which marked the creation of North American Hall and the erection of twenty habitat groups of large mammals—all by gifts—has resulted in Philadelphia's having a bird hall not only different from any other but adapted to the three functions of the academy—research, popular education and public exhibition; none of the functions has been slighted at the expense of another.

The hall is being opened with only two or three cases incomplete, and it is believed that at the opening the cost of these will be subscribed. No academy income is ever spent for public exhibitions. The institution, 130 years old this year, is supported wholly by gift and from the income of a small endowment. It receives no public funds. Income goes for the support of research in the more than a dozen scientific departments and for scientific publication and the upkeep of the building. Public exhibitions in the museum are the result of special gifts for specific purposes.

The new hall is named for Audubon for various reasons. The great painter of "The Birds of America" lived for a short but important period of his life on Mill Grove Farm, near Philadelphia. It was there that he met, wooed and married Lucy Bakewell, who proved to be such a help to him in his struggles to achieve his artistic destiny.

It was in the academy in 1824, then at 35 Arch Street, that Audubon, having given up trying to make a living as a merchant in Kentucky, showed his water colors that eventually went into the double elephant folio. It was in the academy membership that Audubon found certain valuable benefactors, notably Edward Harris, of Moorestown, New Jersey. It is true that the academy could not undertake to sponsor Audubon's publication and that by reason of this inability he went to London in 1826, where he found the Havells, father and son, who undertook the great task of aquatint engraving. But Audubon had close relations with the academy, its members and its collections, and was enrolled as a corresponding member in 1831. The academy was fourteenth on the list of subscribers to "The Birds of America" and that set of four volumes is now in the academy's library. It will be exhibited at the opening of Audubon Hall.

Audubon Hall is arranged primarily on a geographic plan. The visitor enters

ONE OF THE SECTIONS OF THE AUDUBON HALL

ARTIFICIAL LIGHT IS USED IN THE NEW HALL, ALL NATURAL LIGHT BEING EXCLUDED.

BUILDING OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA
THE NEW AUDUBON HALL IS HOUSED ON THE THIRD FLOOR OF THE ACADEMY BUILDING.

from a lobby which eventually will contain habitat groups of passenger pigeon and whistling swan and which is decorated with murals of extinct species. In the hall proper he finds alcoves representing the continents. He sees for example, the birds of North America, South America, Europe, Asia, Africa, Oceanica and the Arctic regions in order. Then he comes to exhibitions showing the evolution of birds, distribution, migration, nesting, economic relationships to man, and the extinct species, of which the academy owns a notable collection. In a separate room are the birds to be found within fifty miles of the academy.

Close attention has been paid to legi-

AN EXHIBIT OF THE BIRDS OF NORTH AMERICA
IN THE NEW AUDUBON HALL THERE ARE MORE THAN FORTY SUCH CASES ARRANGED IN ALCOVES WITH BACKGROUNDS PAINTED IN NATURAL COLORS.

A MUSEUM PREPARATOR AT WORK
THE LIFE-LIKE MOUNTS HAVE BEEN ASSEMBLED ACCORDING TO THEIR GEOGRAPHIC DISTRIBUTION.

ble, simple labelling, to charts comprehensible to students of various ages, to maps, diagrams and models where such things are needed to tell the complete story. The hall's educational function has been worked out so that the classes from the public and private schools which come to the academy for instruction by the educational department under Charles E. Mohr can have the maximum benefit with the least expenditure of time and energy.

The lay visitor and the professional ornithologist have also been considered, so that the pattern of the four rooms will furnish the greatest satisfaction and—the academy hopes—the least criticism. On the floor below is the academy's library of natural history, with its bird section of books and continuous files of journals in many languages. The academy members and ornithologists therefore will have together in one place the materials for bird study in the most convenient form available.

Color, lighting and the comfort of the museum visitor have all been worked out so that objectionable features of the old-fashioned museum bird hall will be markedly absent. The hall and all parts of the museum are free to the public.

M. H.

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BIOLOGICAL ADAPTATION

By THEODOSIUS DOBZHANSKY

PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY

ORGANISMS are said to be adapted to their environment, because they are built and act in ways which enable them to survive and to propagate their kind in the environment in which they normally occur. To an observer, a living being seems to be designed to attain the goal of survival and reproduction; it appears to strive not only to retain but to expand its hold on the environment. Most biological phenomena display an apparent purposefulness of a kind which we do not perceive to exist in inanimate nature. The concept of purposefulness belongs, however, to the realms of human affairs, of metaphysics and of religious philosophy; it has not so far justified itself as a tool of discovery in the natural sciences. A biologist must, if he can, reduce this concept to terms which are capable of serving as such tools. The difficulty of this task is formidable; it has not been completely accomplished, despite the fact that some of the greatest minds in biology have devoted their efforts to the solution of the problem of adaptation. The present status of this problem is outlined in the following paragraphs.

I

When a problem is very difficult, attempts are usually made to dodge it by denying its existence. Such attempts are not as illegitimate as they seem: many a scientific "problem" of bygone days has been shown to be spurious. This is, however, not the case with adaptation. It has been suggested that the alleged adaptations are mere anthropomorphic judgments, and that it is enough to describe how organisms are built and are functioning without imputing to their structures and functions any kind of aim or purpose. Unfortunately, this "solution" of the problem of adaptation is akin to the behavior of the proverbial ostrich hiding its head in sand. The adaptability of life is too evident to be dismissed so lightly, and it is not sound practice to restrict scientific description within set bounds. Consider, for example, these facts: when we ascend high mountains the composition of our blood changes in such a way that our toil is made easier; when our body is invaded by germs, it reacts in a manner which destroys or at least restricts the spread of the invaders; desert plants possess a whole retinue of devices which prevent excessive evaporation of water, while plants growing in moist places are usually less well protected from desiccation. Indeed, one could describe these and thousands of similar facts without reference to their bearing on the preservation of the existence of individuals and strains, but what useful purpose would be accomplished by this limitation?

Curiously akin to the view which disposes of the problem of adaptation by ignoring its existence is the assumption that purposefulness is an intrinsic prop-

erty of living matter. Both views attempt to settle the question by a kind of fiat. At any rate, since no organism is perfectly adapted to living in all environments and in all contingencies, the purposefulness of life is evidently incomplete. Adaptation is not something given to the organism once and for all time. In the process of evolution the harmony between the organism and its environment is constantly lost and recaptured, and the acquisition of this harmony is never safe or final but requires a continuous exertion on the part of the organism.

II

Up to the present, only two types of scientifically articulate explanations of organic adaptation have been advanced. They are known as the Lamarckian and the Darwinian types, respectively. Their essence and their contrasting features can be stated very simply. Lamarckism supposes that evolutionary changes are adaptive from the time when they originate; that the changes arise in response to the exigencies of the organism's existence; that these changes appear first in the body or in the mind, and only subsequently are fixed by heredity. The basic assumption of Darwinism is that changes originate in the hereditary materials, owing either to forces residing in these materials themselves or induced there by the environment. As they arise, the changes have no intrinsic relation to adaptation: some of them may be harmful, others neutral, and still others useful to their carriers. Adaptations become established owing to the retention of only or mostly those changes which increase the probability of survival or of reproduction of their possessors.

Lamarckism has run into many difficulties, and it continues to exist at present only on the fringes of biology, although it seems to have caught the fancy of some philosophers and speculative thinkers. The principal difficulty of Lamarckism is that it fails to explain why the need for a certain modification of some organ should produce such a modification. It is well known, of course, that repeated use of many organs, *e.g.*, of muscles, strengthens them, while sustained disuse weakens them. These effects of use and disuse are corollaries to physiological mechanisms which regulate the food supply to and the removal of waste products from functioning organs. The existence of such regulatory mechanisms should not, however, be taken for granted; they constitute most important adaptive attributes, and their origin demands an explanation. Furthermore, many adaptive reactions can be described only very loosely in terms of use and disuse. For example, a certain portion of the sun's spectrum induces formation of pigment in the human skin which prevents the penetration of the rays injurious to the internal organs. This is the tanning reaction of the skin which is known to furnish protection against sunburn. How has such an adaptive reaction become established in man's ancestry? The keen analytic mind of Lamarck saw the problem very clearly; Lamarck appealed to psychic phenomena as the primary source of adaptability. This part of Lamarck's theory (psycholamarckism) has baffled his successors (mechanolamarckists) to such an extent that the latter prefer to gloss it over with silence. It is an oversimplification to say that according to Lamarck an organism changes because it wants to do so, but in any case the nature of the supposed connection between mind and adaptation is utterly obscure. As to the mechano- or neolamarckists, they are, in effect, taking for granted the basic fact of adaptability which they pretend to explain.

The difficulties of Lamarckism do not end here. In order to become an integral part of the species, an evolutionary change must become hereditary. The supposition that changes resulting from use and disuse of organs are eventually

established in heredity is known as the hypothesis of inheritance of acquired characteristics. This hypothesis was subject to so much dispute in the early part of the current century that in the popular mind it has become synonymous with Lamarckism itself, although Lamarckism is a theory which is much deeper and broader than this hypothesis. Yet, it is an essential part of Lamarckism. Not many scientific hypotheses have been so widely and so persistently misunderstood as that of the inheritance of acquired characteristics. The problem is, however, simple enough. The question at issue is as follows: can changes appearing in the body in response to environmental stimuli induce *corresponding* changes in the hereditary materials? The correspondence of the changes is the crux of the whole matter. Take again the example of the tanning reaction of the human skin. The pigment in the skin appears in response to sunlight. Heredity is transmitted through the sex cells, or, more precisely, through the chromosomes contained in these cells. Will the presence of the skin pigment so influence the materials composing the chromosomes that in the offspring of the modified individual a greater amount of the same pigment will be deposited than in the ancestor before the latter was subject to the rays of the sun? It is conceivable that physiological changes produced in the body by the deposition of the pigment in the skin might somehow upset the hereditary materials, and might lead to the appearance of hereditary changes in all sorts of organs and functions, *i.e.*, to a general increase of the mutability. But even if such outbursts of mutability were observed (and they have not been observed), the result would tell us nothing about the inheritance of acquired characteristics. The hypothesis demands that acquired changes in the skin color be reflected in those parts of the hereditary materials which determine the skin color of the offspring.

It is fair, I think, to sum up the present status of the hypothesis of inheritance of acquired characteristics as follows. Experiments set up to test the possibility of such inheritance have generally given unequivocally negative results; the few alleged positive instances have not stood the test of critical scrutiny and repetition. This imposes such a strain on the theory that Lamarckists are forced to withdraw to a position which removes the whole question from the realm of the experimental method. It is pointed out, quite justly of course, that experiments involve of necessity relatively short time intervals. Nature has at its disposal incomparably greater time periods. May be, then, acquired characteristics can be inherited after all?

This position is formally unassailable, but no amount of tergiversation can conceal the fact that it is sterile as a working hypothesis. It may also be noted that the hypothesis of inheritance of acquired characteristics implies the existence of a very intimate one-to-one relationship between the body parts and characters on one hand and the discrete particles (genes) representing them in the sex cells on the other. Although the exact interrelations existing between genes and characters are as yet very little understood, biology has been veering away from the crudely preformistic notions according to which the genes borne in the sex cells are like diminutive vestiges of the organs of the adult body. The full import of this consideration is not realized by certain philosophers who profess Lamarckistic sympathies. The road from gene to character need not be a one way street: genes in the sex cells may, perhaps, be influenced by the body carrying them. The problem is how the genes react to influences emanating from the body periphery, and at

present it seems very improbable that identical changes are induced in both.

III

Since Darwin, Darwinism has undergone a complex development and a thoroughgoing modification. Darwin himself had accepted Lamarckism as a sort of subsidiary to his own theory. Neodarwinism, especially in its most brilliant representative, Weismann, led to elimination of all traces of Lamarckism and to erection of the purest "Darwinian" system of views. The period of neodarwinism may be said to have ended with the rise of experimental studies on heredity and variation (genetics). Space does not permit us to follow even briefly this evolution of Darwinism. Our purpose is rather to sketch the most essential parts of the modern system of views, which, if a designation is wanted, may perhaps be labelled inductive Darwinism.

The evolutionary process, of which adaptation is a part, may be likened to a factory having three divisions or levels on which different parts of a manufacturing process are carried out. On the first level the raw materials of evolution, that is the inheritable variations, are produced. Hereditary changes arise owing to forces acting from within or impinging from outside the body of a living individual. Availability of heritable variation is, however, not in itself sufficient to accomplish either evolution or adaptation, just as presence of raw materials in a factory does not insure the appearance of a finished product. Uncontrolled variation would produce a chaos of freaks rather than adaptive changes. The processes which combine the heritable variants into organized systems of traits take place on the second level. Here, then, the raw materials are shaped to become functional forms. Natural selection combines the hereditary elements into the integrated complexes which characterize races, species, or other biological groups adapted to the environments in which they live. Finally, the third level concerns the development of reproductive isolation between incipient species. Reproductive isolation (differences in the mating habits, inviability or sterility of hybrids, etc.) prevents species from exchanging portions of their hereditary endowments, and thus guards against disintegration of the organized adaptive systems formed on the preceding level. In terms of our factory allegory, a sort of packaging of the finished products is accomplished on the third level. It must, of course, be kept in mind that the distinction of the above three levels is made for analytical purposes only, and that in reality the three levels are interdependent.

IV

Here we must make a digression to state certain fundamental principles which ought to serve as a basis of any discussion of adaptation and evolution. For the sake of brevity biologists say simply that this or that character is or is not inherited. But a "character," such as color, size or shape of a certain organ or of the whole body, is merely an outward sign of some physiological process having taken place during the development of the organism. What is really inherited is not a character but the kind of response which is evoked by the environmental stimuli in the living organism. The appearance of an individual (its "phenotype") is determined by interaction between its heredity (its "genotype") and the environment in which the development is taking place. To illustrate: the skin color in man is said to be an inherited character; but it is generally known that the color of our skin depends upon external conditions, such as exposure to sunlight. Human stature is also inherited; yet, an individual grows taller or shorter depending upon diet, mode of life during childhood

and adolescence, the diseases suffered, etc. What is meant by inheritance of skin color and stature is that a given hereditary constitution will produce a certain skin color and a certain stature in a given environment. Different genotypes in the same environment may result in different skin colors and statures; the same genotype in different environments may or may not give different skin colors and statures.

In a given environment, certain genotypes may produce characters which are beneficial to their carriers, and will enable the latter to survive and to leave offspring. In the same environment, other genotypes may be unfit for survival. The general fitness of a genotype, its adaptive value, is evidently a function of its response in different environments. The adaptation may be a specialized one: an organism may react purposefully to the stimuli emanating from only that particular environment in which it normally occurs. A more generalized adaptation permits the organism to survive and to reproduce in a wide variety of environments. Thus, some insects require for food a definite species of plant or a definite kind of prey; other insects are more nearly omnivorous. Sumner and Sargent have shown that a certain species of fish found in warm springs in Nevada may survive for some time in springs of normal temperature, although its relative found in the latter is killed in the warm springs. An ideal adaptation would permit the organism to survive in all environments. Such a paragon does not exist: man's response to environments is doubtless the most effective one which has been evolved on earth and possibly in the Cosmos, but it falls far short of the ideal.

The variety of adaptive responses which an organism is capable of producing is great. We have already mentioned several such responses in man: the tanning reaction of the skin, changes in composition of the blood at different altitudes, reactions of the body to invasion by disease-producing germs. It is impossible to tell which of these responses are more and which are less important: that obviously depends on the environment. But it is fair to say that the adaptive value of a genotype is a function of all these responses.

The mechanisms which transmit heredity from parents to offspring can not be described here. Suffice it to say that modern biology has firmly established the fact that the hereditary materials are not a continuous mass but the sum of more or less discrete particles known as genes. Borne in the chromosomes of cell nuclei, the genes are independent in that in the process of variation they may change one by one (see below). The genes of an organism constitute its genotype and determine the response of that organism to the environment. The subtle relations which exist between separate genes and separate "characters" need not be discussed here, but it is very important to realize that the adaptive value of a genotype is determined by all the genes acting in concert. To put it differently, a functional genotype is not simply an array of genes each of which performs its function independently of the others. A genotype is an exquisitely adjusted system, in which the genes are closely comparable to separate workers tending an assembly line in a factory. Alteration or deletion of a single gene may modify some of the organism's responses to the environment, while other responses may or may not be left unchanged. Nevertheless, the adaptive value of the whole genotype very frequently depends on the behavior of a single gene. Furthermore, the adaptive value of a combination of genes is not predictable on the basis of the knowledge of the effects of each of these genes taken singly. Thus, the gene A may be favorable in combination with B but unfavorable in combination with C, while the gene D may be favorable with B and C

but not with A. Hence, evolution and adaptation may involve not merely a substitution of a gene here and a gene there but a change of the whole structure of the genotype. This is analogous to the thorough change which must be made in an assembly line if it is to produce tanks instead of automobiles or *vice versa.*

V

Hereditary variants arise chiefly, if not exclusively, through discrete steps termed mutations. Some mutations, such as the origin of a sheep with legs resembling those of a dachshund, were known to Darwin, who considered them too rare and too drastic to be of importance in the process of adaptation. De Vries, the founder of the mutation theory, also thought that mutations produce great departures from the ancestral type. As more mutations were found in diverse organisms, it became clear that the extent of changes induced by mutations varies greatly. Not only are the alterations produced by some mutations so small that refined techniques are required for their detection, but small mutations prove to be much more frequent than large ones. The common "fluctuating" variability, such as the variation of the human stature, body proportions, hair color, etc., can be described as compounded of mutational elements. However, regardless of size, the mutational steps are discrete: no intermediates between the original and the mutant conditions can be detected. It is this discreteness rather than the extent of the change that characterizes the mutational variability. Most, although not all, mutations represent changes in a single hereditary element, a gene.

The frequencies with which genes mutate in different organisms, and those with which different genes mutate in the same organism, are variable. Haldane infers that the gene for haemophilia (bleeding) in man mutates once in about 50,000 life cycles; Timofeeff-Ressovsky estimates that in the fly *Drosophila* between 2 and 3 per cent. of the sex cells contain newly arisen mutants in one or more genes. All sorts of changes arise by mutation: alterations of superficial and of anatomical structures, of physiological and psychic (reflexes, habits) functions, modifications localized in a small part of the body and upsets of the basic developmental patterns. Mutations occur almost always singly, among masses of unchanged representatives of a strain.

A mutation gives rise to a new hereditary variant, a mutant. The response of a mutant to the environment is different from that of its ancestor. From the standpoint of adaptation, the value of a mutant depends upon the fitness of its reaction to the environment for survival and reproduction. Several possibilities present themselves. A mutant may be neutral, *i.e.*, it may survive and reach the reproductive stage of the life cycle as often as the original type, the average fecundity being the same as in the original type. Neutral mutants are always present in populations of living species. For example, practically all human races and strains are mixtures of several hereditary types differing in the composition of their blood (the "blood groups"); as far as known, the blood groups are equivalent with respect to their survival values; the genes responsible for the blood groups are adaptively neutral. A mutant may, however, survive more frequently or may leave a more numerous progeny than the original type in the same environment in which the latter normally occurs. This is a favorable mutant, and it will tend eventually to supplant the original type. Still other mutants may respond to the environment in which the species normally lives in a manner less favorable than the original type does. The mutants may, however, have an advantage over the ancestral type in some environment or environments in which the species occurs but

rarely or not at all. The species will, then, be split into two or more races, each a master of its special domain. For example, Banta and Wood have observed a mutant in the water flea which survived with difficulty at the temperature at which the species normally lives, but which was able to exist at a higher temperature fatal to its ancestor. Many plant species are differentiated into races living in valleys on one hand and in high mountains on the other; the plants of the mountain races suffer if transplanted in the valley, while the valley plants die off if planted in mountains. Finally, a mutant may respond unfavorably in all existing environments, or at least in all environments which the species is able to reach. Such a mutant can not become established anywhere, but, since it may continue to arise from time to time by mutation, it will recur sporadically as a phase, an aberration, or a monstrosity. Genes producing pathological effects, such as the above-mentioned haemophilia mutants in man, belong to this class.

The foregoing paragraph contains a condensed statement of Darwin's theory of natural selection in its modern form. Natural selection is at the same time the judiciary and the executive agency of the environment. Every genetic variant is evaluated according to the fitness of its reactions for securing or retention of a foothold in some niche of the environment. The fit variants are multiplied, and may become established to the exclusion of all others. The unfit ones are reduced in frequency or eliminated. It should be noted that there is no absolute minimum degree of usefulness which a variant must possess before natural selection comes into play. No life-and-death utility is needed. If the offspring of two variants survive in a ratio 999 : 1000, the frequency of the fitter variant may increase in time.

The early protagonists of natural selection have in their crusading zeal grossly exaggerated the ferocity of the struggle for existence which promotes adaptation. An unsuccessful mutant need not be immediately pounced upon and stifled by its competitors from among the members of the same species. The elimination of unfavorable genotypes can be described more adequately as taking place through non-perpetuation rather than through outright destruction. It is, of course, true that, as first pointed out by Malthus, only a fraction, and frequently only a small fraction, of the offspring produced by any one species reaches adulthood. But these Malthusian hecatombs are for the most part blindly accidental rather than differential or selective. The differential survival which is the keystone of natural selection is a more subtle process.

Since evolutionary changes taking place in nature are based mostly on small differences in the survival values of the competing variants, the process of transformation is in general too slow to be noticeable within the limits of a human lifetime. Evolutionists were constrained to acknowledge that evolution has not been observed directly but only inferred on the basis of circumstantial evidence. Although major transformations can still be neither witnessed in nature nor reproduced in the laboratory, some evolutionary changes have been recorded. The splendid work of Quayle, Dickson and their colleagues has demonstrated that new races have developed and are developing in certain scale insects in the citrus orchards of California. These races show a greater resistance than the original types to fumigation with hydrocyanic gas which is regularly practiced in the citrus groves for the purpose of pest control. Since 1913 the appearance of cyanide resistant races has been recorded in at least three species of scales, and in one of them the resistance is known to be due to mutation in apparently a single gene. There is no doubt that the spread of the resistant races is due to natural selection, the fumigation

with hydrocyanic gas being the selective factor. There is a growing body of evidence of a similar kind in other organisms as well: emergence of a race of the coddling moth adapted to walnut instead of to apple, changes in the composition of populations of certain rust fungi and of a species of the flies *Drosophila*.

VI

Natural selection causes the spread and establishment of favorable variants and elimination of unfavorable ones. However, it continues to operate only so long as there is available a store of heritable variants which differ in their reactions to the environment and in adaptive value. Natural selection merely selects variants from the accumulated stock, but it does not itself produce new variants; natural selection does not induce mutations. This is the basis of the oft-repeated assertion that natural selection creates nothing new and is a conservative factor. This assertion is true in a sense, but it is highly misleading unless its precise meaning is understood very clearly.

First of all, how great is the stock of variants accumulated in natural populations? As pointed out above, the transmission of heredity from parents to offspring is accomplished through particles termed genes. Exactly how numerous are the genes is in no case known, but estimates for organisms as complex as an insect range in thousands. Each gene is capable of giving rise by mutation to several modifications. Now, the mechanism of sexual reproduction, the corollary of which are the laws of Mendel, operates to produce all possible combinations of the available diversity of genes. Assume that a pair of parents differ in three genes—one parent being ABC and the other abc. Among the grandchildren there will appear the gene combinations ABC, ABc, AbC, aBC, Abc, aBc, abC and abc. Every gene combination has its own response to the environment, and hence its own adaptive value. Some of these combinations, for example, ABc, AbC and abc, may be favorable and the remainder unfavorable. The favorable gene combinations must arise before they can be judged by natural selection; mutation produces gene variants, but sexual reproduction is the magnificently efficient mechanism which produces gene combinations. This role of sexual reproduction was not at all sufficiently appreciated in Darwin's time.

Sewall Wright points out that if one makes the very conservative estimate that there are 1,000 variable genes each modifiable by mutation in 10 different ways, the number of possible gene combinations turns out to be 10^{1000}. This figure is fantastically large; it has no analogue in the world of reality (the number of electrons and protons in the visible universe is thought to be of the order of 10^{300}). Indeed, nothing can be more certain than that only a very small fraction of the potentially possible gene combinations have ever been realized in nature and tried out by natural selection. Yet the number of existing gene combinations is also enormous—it is virtually certain that, for example, every individual human being (identical twins excepted) possesses a gene combination not present in any other individual now living or having lived. When applied to an agent which selects or rejects variants from so colossal a store as this, the adjectives "creative" and "conservative" assume quite other than their usual meanings.

The uniqueness of every human individual we recognize as manifested in his appearance, and take it largely for granted. Yet the hereditary variability is much greater than its external manifestation might lead us to believe. Certain genes (Mendelian recessives) may be carried in the hereditary materials of an individual in a concealed condition, but their external manifestation may be only delayed and may come to light in the offspring. Recent studies have shown

that natural populations of sexually reproducing species harbor a hitherto scarcely suspected wealth of concealed hereditary variability. A closer examination of this concealed store of variability shows that its constituents are mostly harmful to the organism if permitted to manifest their action. The sexual reproduction is, however, incessantly shuffling and reshuffling the gene elements in this store. Ever new gene combinations are being formed. Genes which are deleterious in some combinations may be favorable in other combinations. Variants which are incapable of survival in one environment may be suitable in other environments. Moreover, the environment is seldom static not only on geological but even on human time scale. A trait useful in New York may be utterly useless in a tropical jungle; a peculiarity superfluous to-day may be valuable tomorrow. Certain observations on natural populations of flies belonging to the genus *Drosophila* suggest that the adaptive plasticity of living species has been much underestimated. Changes adjusting a species to various phases of its environment, even though these phases may be of a very temporary nature, are taking place continuously, and their speed is appreciable enough to be observed directly.

VII

Much has been written about the improbability of "chance" producing adaptive modifications. Can adaptive structures and functions arise by summation of the occasional useful variants? The difficulty appears to be especially formidable where complex and beautifully balanced organs, such as the human eye, are concerned. It is equally difficult to visualize the origin of the physiological correlations and interrelations between various organs and functions of the body which are accomplished, as we know or suspect, through an intricate system of chemical messengers and nervous stimuli. Could, for example, the series of physiological changes taking place in the woman's body in connection with pregnancy and childbirth have developed by natural selection combining numerous mutants? And what about the unbelievably complex structure of the human brain? The problem is aggravated further if one compares the systems found in different organisms, say a fish and a mammal. For it seems that each of these systems is balanced so delicately that it can function only as such —intermediate systems or systems combining the features of the two would be absurdly incoherent and unfit to survive.

The following analogy, or its variants, have been suggested to illustrate the above difficulty. Imagine monkeys shaking boxes containing printer's type; could the letters ever arrange themselves by chance to produce Dante's Divine Comedy? At first sight, this difficulty, which had already perplexed Darwin, appears wellnigh insuperable, so much so that it has made all forms of Darwinism unacceptable to many thinkers in and out of biology. There is no use pretending that this difficulty has been satisfactorily solved. A way toward its solution may, however, be discerned. Two main considerations must be brought forward in this connection. First, we have become aware of the existence in nature of a trial and error mechanism on a scale scarcely suspected in Darwin's and even in Weismann's times. Sexual reproduction is a marvelously efficient "shaker" of the biological letters. Furthermore, and this is the main point, the "monkey analogy" misconstrues the situation in that it overlooks the historic aspect of the process of adaptation.

Organs and functions have not arisen at once in the state of the relative perfection which they now exhibit. Mutation and selection have not created them overnight from inorganic substances. They have developed from humbler beginnings, from simpler organs and functions. Yet, these ancestral organs and

functions had an adaptive significance to their carriers. Surely the organisms of the past were just as capable to survive in their environment as the now living organisms can in theirs. The progenitors of the living beings of to-day possessed genes and responded to their environments through their organs and functions. Returning to the "monkey analogy," the shaking of the printer's type need not produce the Divine Comedy complete to the last letter. In so far as this analogy is at all fit to illustrate the process of biological evolution, it should be stated as follows. A chance concatenation of letters had produced only the first verse, and as soon as that appeared the letters composing the verse were bound together. The second, third, and the following stanzas were formed and added to the first. Thus, the Divine Comedy grew and developed, the beauty of its parts as well as that of the whole design unfolding step by step. Seen in retrospect, the process reveals the inspiration of the poet, although each verse arose, if you will, by chance. A better analogy would be to compare organic transformation to the development of a poetic work from its inception in the poet's mind to the final stage in which we know it. Indeed, there might have existed many sketches and drafts of the Divine Comedy containing verses which were subsequently deleted but lacking verses which appear in the finished masterpieces.

It is, hence, only a very partial truth to say that inductive Darwinism builds its theory of adaptation on chance. Oddly enough, some of those writers who are most impressed by the difficulties of conceiving the occurrence of adaptive evolution under the control of natural selection make much greater appeals to chance in their alternative theories. Among the recent speculations, by far the greatest role is ascribed to chance in Goldschmidt's theory of "systemic mutations." Goldschmidt does not believe that summation of mutational steps could ever lead to anything greater than a few changes in the details of organization. Major evolutionary advances are ascribed to entirely hypothetical systemic mutations which produce in a single leap radically different organs and functions. The systemic mutants are characterized by Goldschmidt himself as "hopeful monsters" whose hopes are fulfilled very rarely. According to this theory, then, the Divine Comedy must appear almost complete, natural selection being able to make only minor corrections in the printer's proof.

The evolutionary transition from one integrated adaptive system, such as fish, to another system, such as mammal, presents difficulties on any theory yet proposed, since, as pointed out above, intermediate systems would seem to be poorly balanced. Indeed, some paleontologists believe that the beginnings of most major biological groups are conspicuously absent or rare in the geological record. Provided this belief is justified, we are forced to admit that evolutionary transition is sometimes a painful process, leading to a temporary eclipse of the group of organisms which is in the throes of reconstruction. This may have a profound biological significance. Modern genetics indicates that conditions most favorable for rapid evolutionary development may occur more frequently in species that are rare and broken up into numerous isolated populations than in very common and widespread species. It may be that the forms of life that are most successful on a given geological level are not the progenitors of the living beings dominating the next geological age. There may exist a kind of super-selection demanding that an organism passes through an eclipse if it is to inherit the world of to-morrow.

VIII

The magnitude of the store of hereditary variability available in nature and the great potentialities of the trial and error mechanism furnished by sexual

reproduction in conjunction with natural selection permit us to visualize the process of formation of adaptive genotypes. But the problem of adaptation is not yet solved thereby. Hereditary variants arise, as we know, by mutation. Mutations are frequently changes in a single gene (some mutations entail reduplications or losses of whole chromosomes or groups of chromosomes, but these kinds of mutations play, on the whole, a subordinate role in evolution, and we need not consider them here). Some gene changes may improve the adaptive response of the organism to its environment. Is, however, the need for a given kind of mutation somehow capable of producing that mutation? For unless the hereditary elements from which an adaptation could be constructed are available, natural selection is powerless to remedy the situation.

Neither the structure of the gene nor the nature of changes which genes undergo in mutation are sufficiently well known at present. Genes are particles borne in chromosomes of cell nuclei. They may be single organic molecules, or groups of molecules, or else a whole aggregate of genes constituting a chromosome may be a supra-molecular system the parts of which are somehow interdependent. A gene mutation is probably a chemical alteration taking place in a portion of a chromosome. Such alterations arise spontaneously from time to time in all organisms studied in the respect. The frequency of mutation may be increased one hundred fold or more by x-ray, by ultraviolet radiation, and perhaps by certain chemical treatments. But with the exception of certain transformations in the microorganisms producing some forms of pneumonia in man (pneumococci), we can not induce at will a given mutation in a given cell. The mutation process is not yet under human control. Mutations just happen.

The temptation to cut the Gordian knot is great—some biologists explicitly or implicitly assume that in nature the mutation process may somehow be directed by environmental influences into useful channels. Suppose, the climate of the country in which an organism lives grows colder; could this climatic change induce mutations improving the response of the organism to cold? Exposure of the human skin to sunlight results in an increase of the skin pigmentation; is sunlight likewise producing mutations which make the organism manufacture more and more pigment? It is pointed out that, since the causation of mutations is unknown, this possibility must be at least considered open. Unfortunately, what we do know about the mutation process belies this reasoning.

The existence of a biological function which a mutation might fulfill does not seem to induce that mutation. Mutations occur regardless of their potential utility. The profusion of species which once lived but became extinct attests the fact that the mutations which are necessary to maintain the harmony between an organism and its environment are not always produced. As to the possibilities in the realm of the unknown, we would do well to examine the implications of a theory before we agree to adopt it even for speculative purposes. Suppose that genes do respond to the impact of each type of environment by producing only certain mutational changes. The survival value of a mutant is determined not by the changed gene alone but also by its interactions with other genes present in the same organism. The adaptability of an organism depends upon its entire hereditary endowment. To assume that an organism responds to the demands of its environment by producing only or even mainly those mutations that specifically answer these demands would mean that the organism has a prescience of the future. This is tantamount to the assumption of an intrinsic purposefulness of the living matter. On closer examination the theory of adaptive directedness of mutations falls under its own weight.

Mutations are often said to occur by chance or at random. These epithets are justified only in so far as they imply that mutations are not inherently purposeful at the time of their origin. The survival value of a mutant is a function of the time and place in which it appears. Otherwise, the mutation process is controlled by the organization of the living matter in which the changes arise as well as by the physical environment. Although very little is known about these controls, the following facts are relevant. Some genes change by mutation more often than others. Thus, in the fly *Drosophila,* mutations changing the normal red eye color to white or to intermediate shades have been observed certainly more than one hundred times, while the origin of some other mutant types has been recorded only once. Timofeeff-Ressovsky found that in a certain strain of Drosophila the gene giving rise to the white-eyed mutation is more stable than in a certain other strain, and that in one strain this gene gives rise chiefly to eye colors intermediate between red and white while in the other most of the mutants are pure white. In rapidly developing organisms like Drosophila the general mutability is much higher per time unit (although not necessarily so per generation) than in the slowly developing human. This fact may, indeed, be considered an adaptation: with a mutability as high as it is in Drosophila man's chromosomes would be loaded with mutants within few generations.

One of the properties of genes which is known with certainty is that genes are self-reproducing entities. Any gene, if it is to persist from generation to generation, must be able to build a copy of itself from the materials available in the cell. Not all cell constituents are endowed with the capacity of self-reproduction. It may be that this capacity is confined to genes alone, and that the growth of the remainder of the cell is governed by the genes. However that may be, the freedom of mutational change is decidedly limited: unless a mutation results in a physical destruction of the gene, it must be a kind of change which does not deprive the altered gene of its ability to reproduce itself. Now, self-reproduction is, from a chemical standpoint, a very startling property. It must of necessity presuppose a very special, and as yet completely unknown, chemical structure. Thus, a gene is a body which must have arisen by a historical process which a biologist is tempted to call natural selection. The gene embodies, or at least shares in, the most fundamental, and yet frequently overlooked, attribute of the living matter: it carries its history within itself.

Viewing a living organism as the outcome of a historical process may help us to comprehend what is otherwise a mystery: how can what seems to be a blind chemical change in a gene lead to furtherance of the harmony between the organism and its environment? This problem is, after all, a part of a more general one: how can a living body be built of chemical substances? A living being is, in its physical aspect, a bundle of chemicals arranged in a certain pattern. But looked at from a biological angle, a living being is a system so designed as to be to a maximum degree attuned to its environment and able to perpetuate itself in the process of reproduction. Any change in this system must, in the last analysis, be physicochemical in nature. Yet, the components of the system as well as the pattern in which they are arranged are sequels of countless generations of natural selection and embodiments of the organism's history.[1]

[1] The writer takes pleasure in acknowledging the help received from Professors Jacques Barzun, L. C. Dunn, C. C. Epling, Selig Hecht, Miss A. M. Holz, Professors A. Mirsky, M. M. Rhoades, H. B. Steinbach and Mrs. Steinbach, who have read the manuscript of this article and suggested changes and improvements in presentation.

FOOD AND FITNESS

By Dr. A. J. CARLSON

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OUR country produces probably the greatest variety and quantity of good foods. Are we making the most of this resource for optimum health? For the last ten years we have been told that one third of the American people are ill fed, that these forty million American citizens suffer from malnutrition. Is this true? And if it is true, what are the reasons for it, and what can we do about it? In fact, very recently we were told much more. At the National Conference on Nutrition for Defense, held in Washington, D. C., a year ago, Dr. Thomas Parran, chief of the U. S. Public Health Service, said: "Studies of family diets by the Department of Agriculture in all income groups of the Nation show that one third of our people are getting food inadequate to maintain good health" and "less than one fourth of us are getting a good diet." If this is true, that makes it, not forty million, but about one hundred million Americans with an inadequate diet, from any and all causes. The question is: Is this true? These alarming claims for national malnutrition appear to be based primarily upon a series of surveys conducted by the Bureau of Home Economics of our Federal Department of Agriculture, assisted in some of the field work and statistical analysis by the Department of Labor. These surveys embraced some 4,000 urban and village families of various levels of income and some 2,000 rural families of varying levels of income, selected from representative regions of our country. The surveys consist in reports from these families as to how much money they spent for food, and what kinds of food were bought, and, in the case of rural families, how much and what kind of food they consumed from the crops on their own farms. These field investigators (some of them on WPA) had to take or did take the people's word for all these alleged facts. It is impossible to determine the degree of accuracy or honesty (accuracy as to memory) of whatever member of these families gave the facts or alleged facts to the enumerators.

Nor do the surveys indicate the amount of foods actually eaten or the amount of food wasted. The latter factor is probably not inconsiderable, particularly in the families of the higher income groups. I know of no statistics on this point, but on the whole, my experience indicates that the food waste at the table increases with the economic prosperity of the family.

On the basis of the kind and quantity of the food bought or grown on the farms, the Bureau of Home Economics estimated the diets of these families as excellent, good, fair or poor. We wish to point out that no physical or medical examination was made of the members of these families. Not even such a simple physical fact as the determination of the body weights of the people involved seems to have been undertaken. I can only express my great regret that the value of these statistics must so largely be left up in the air as regards evidence for good or bad nutrition in our country by neglecting such an obvious factor as medical evidence of the health status of these people concerned. Good medical examinations of members of around 6,000 families in our country does not seem a superhuman task. I feel certain that if competent medical men in the U. S. Public Health Service, in the Bureau of Home Economics of the Department of

Agriculture or in the Federal Department of Labor were not available, a suitable approach to national and state medical societies would have resulted in cooperation sufficient to carry out such a medical survey at little or no cost to the government. The surveys as conducted were made at considerable cost to our tax-paying citizens.

Is that the only evidence of national malnutrition? Do our hospital records, our mortality statistics, our medical examination of our young men for the Army and the Navy point to a nation-wide malnutrition in America? Mortality statistics, even were they reliable, would only reveal extreme malnutrition. They would not tell us much about early stages of malnutrition. Between three and four thousand people are recorded as dying from pellagra (a disease due to an inadequate diet) each year. There is no recent rise in this category. Of course, there are many more people sick from pellagra than people who die from this disease, possibly as many pellagra patients as 100,000 in our country each year. Advanced scurvy is now almost unknown in the United States. Beriberi is somewhat less rare, especially if we include those cases due primarily to chronic alcoholism and consequent failure to eat enough good food. Rickets is not a killing deficiency disease. We may have anemia from too little iron in the diet; but lack of iron is just one of the many causes of anemia. So national mortality statistics fail to answer our question, but so far as they go, they do not point to a state of well-nigh universal malnutrition in the United States. And the same is true of records of our hospital admission. Of course, you may reply that doctors do not recognize early stages of malnutrition. Well, if physicians don't, are WPA workers and Washington politicians any more competent in this field? According to Colonel Rowntree, M.C., U. S. Army, the first 800,000 Army draftees of 1941 examined were on the average 67½ inches tall, or of the same stature as our 1917–18 Army draftees, but our 1941 draftees averaged 8 pounds heavier than those of World War I. According to General Hershey rejections of draftees on account of underweight are so far about the same as the rejection for obesity, or each around 4 per cent. So you see even the story of our draftees does not point to a universal and demonstrable malnutrition. According to the *Statistical Bulletin* of the Metropolitan Life Insurance Company, the average length of life as computed on the basis of mortality of the company's industrial policy holders in 1941 was 63.42 years. This is an all-time high for the sixty years that the company has recorded this information. This does not support the claim that one hundred million Americans suffer from malnutrition. But I am not willing to go all the way in supreme optimism, as does Mr. J. R. Hildebrand (*National Geographic Magazine*, March, 1942), who asserts that our "machine food age—born of roads, research and refrigeration—has made the United States the best-fed nation in history." We have the food to do it, had we the intelligence.

Well, what happens to us when we do not eat enough good foods? Can we know, without asking a doctor, when we suffer from malnutrition? And if we ask the doctor can he tell us when and what? The simplest situation is this: Assuming absence of chronic diseases, if an adult does not eat enough for energy needs he loses weight, if a child does not eat enough for energy needs he soon ceases to grow. Any layman can strip and step on the scales. The physical and mental impairments following prolonged inadequate intake of essential protein, essential fatty acids, essential inorganic salts and vitamins are more insidious. They can not at present be diagnosed even by the physician, unless they are well advanced, and by exclusion of many other

factors that may produce similar symptoms—such general symptoms as decreased physical and mental endurance, decreased appetite, etc. The anemias we encounter in the population are usually not due to too little iron in the diet. Nervous disorders and poor intelligence are very rarely due to vitamin deficiencies. The signs and symptoms of such dietary deficiency diseases as scurvy, rickets, pellagra, beriberi, "war" edema (protein deficiency) any up-to-date doctor can detect and eliminate. But no one (doctor or layman) can be sure in regard to the early stages of these dietary deficiencies. We have recently been told by a national committee of physicians, who should know, that one of the first signs of malnutrition is decreased appetite, and that laymen can diagnose their own state of nutrition by the state of their appetite for food. This is too good to be true. If it is true, and it is also true that one hundred million fellow citizens suffer from malnutrition, it is clear that the American appetite for good food is sunk, and that it probably will take something more potent than synthetic vitamin pills to restore it to a level of national safety.

This sounds discouraging, if not alarming, at least to laymen. Must our national safety and well-being in the matter of nutrition be thus left in the fog, pending further medical and nutritional research? Not at all. America is a paradise in the matter of abundance and variety of all the foods requisite for an optimum human diet. And if we are average normal men and women, we still have our primitive urges of hunger and appetite, notwithstanding recent published assertions to the contrary. How do you suppose our ancestors carried on, in the total absence of modern knowledge of food chemistry, vitamin requirements and the alleged necessity of "a pint of milk a day"? I do not think Sioux Indians got much milk from the wild buffalo. The American Indian had neither cows nor goats. And yet he carried on. It is evident that for the greater part of human history man did very well nutritionally by eating enough of all available varieties of natural foods, guided by his hunger and appetite. Nutritional safety lies in omnivorousness, in consuming, so far as possible, foods in their natural states, and, in the case of fruits and vegetables, eating some of them raw. Some of our malnutritions started with the processing, the refining and the "purification" of such foods as the cereal grains, modern milling processes shunting the most valuable part of these natural foods into the mouths of chickens, cattle and hogs. The cereal grains hold valuable proteins, vitamins and minerals. Human dietary safety on this front would seem to be: Go back to first principles—putting the whole grain into the flour and the bread. This can be done. We can learn to like it. There is no more "purity" or nutritional virtue in white bread than in white winter butter. I think we could learn to prevent the oxidative rancidity of whole grain flour. And until we have that problem licked, what is the matter with storing the wheat and milling the flour as we need it? I do not see any essential economic principle in storing the flour in place of storing the wheat. In my judgment, the recent addition of a little of the vitamins and minerals now milled out of the grain and singing peans of dietary salvation over this "enriched" flour and bread is not a sound policy either for to-day or tomorrow. Let us get back to first dietary principles on this front also. The whole wheat, rye or rice grain is one of our least expensive protective foods. On the whole we can trust nature as to the genuine nutritive elements in the whole grain—yes, trust nature further than the chemist and his synthetic vitamins. Recently, Professor Drummond (*Journal*, American Medical Association, March 7,

1942), the scientific adviser to the British Ministry of Food, voiced this reluctance to put the dietary safety of a nation on synthetic vitamins as a long-range policy. He thinks we must and should provide the natural vitamins in the natural foods. I stand on that platform, until we know a great deal more than we know to-day about foods and human nutrition.

How vital are vitamins? What happens when our breakfast, lunch and supper do not adequately balance with all the known vitamins every day in the year? The vitamins are vital. Even the kangaroo and the crow do not get on without them. They get all the vitamins required in their natural food. So did our ancestors. So could we. On an adequate abundance of natural foods we store vitamins in the body against weeks and months of vitamin scarcity. If we live mainly on such vitamin deficient foods as white bread, polished rice, fat salt pork, refined sugars, refined and hydrogenated vegetable oils, refined lard, etc., serious things happen to our health when our body stores of vitamins are depleted or nearly depleted. It should be obvious to all laymen that every meal every day does not need to be vitamin balanced. Our body stores take care of our urgent needs for weeks or months, unless we have already subsisted on the minimum for some time. It is a fact that an adult man in average good health can go without any food whatever for at least forty days, without showing any recognizable vitamin deficiency. At the end of a forty-days fast the man is considerably emaciated and more readily fatigued, but his appetite for good food is keener than ever. There is to-day entirely too much blarney and ballyhoo about synthetic vitamin pills. Under any and all circumstances these pills are said to give us the abundant life, including intelligence, mental stamina and moral conduct! The tragedy here is this: Few if any of the people who can afford to buy these pills need them, few if any of those who need them can afford to buy them. The consumer should insist that advertising of food conform to honest and factual education of adults in nutrition, for it is obvious that the consumer pays the freight of all food advertising in the increased cost of the advertised foods.

We are urged to drink milk, and to eat meats, eggs and vegetables for our needs of inorganic salts. Is that a good insurance? Is it enough? Can we get adequate mineral insurance at less cost through other foods? While it appears true that herbivorous mammals have sought "salt licks" for countless ages, and our forebears fought wars for possession of sea salt as their more sophisticated descendants now do battle for crude rubber and mineral oil, it seems obvious that except for the element iodine in restricted areas of the earth the dietary needs of minerals were efficiently met by the common non-purified, non-processed natural foods. So far as I know this would still hold true, except for the cooking of such foods as meats, fruits and vegetables and the habit of discarding the cooking water. To be sure the otherwise excellent natural food, milk, is so deficient in iron that an exclusive or almost exclusive diet of milk for weeks or months brings on an anemia due to the iron deficiency in the diet. How does the American dietary stand as to some of the essential mineral needs such as calcium, phosphorus, iron and iodine? The iodine deficiency in the States whose soil and water were depleted of iodine by the waters from ancient glaciers is now taken care of by putting the iodine back into our table salt. The iodine was there before our ingenious chemists learned to take it out. In so far as purification deteriorates our food, the science of chemistry does not serve man's welfare. Professor C. H. Sherman, of Columbia University, an outstanding expert on nu-

trition, has long held the view that the American diet is probably too low in calcium and possibly in phosphorus for optimum nutrition. This problem is complicated by the fact that a modicum of vitamin D is involved in the adequate absorption and utilization of calcium and phosphorus, particularly in the growth and maintenance of our bones. *Can not the possibility of a dietary danger in this field be met, universally and without cost, by adding a little calcium, phosphorus and iron to our table salt?* This should offer no insurmountable difficulties, and there is no evidence that a slight excess above actual needs of these minerals works any injury to our health. We are urged to eat milk for its calcium. Yes, milk is a good source for lime. But milk is a relatively expensive food, and even in our country, with a plethora of foods there is not enough milk to go around, at least as long as we insist on butter and cream for our table and turn so much of the valuable skim milk into channels other than human food. I think we should put a little lime, phosphorus and possibly iron into our table salt as a national insurance towards good nutrition. But I wonder how many vitamin B pills we must consume before we nurture sufficient intelligence to take this apparently rational step.

It seems clear that we do not know the extent of malnutrition in our country. But some malnutrition, especially pellagra, obesity, underweight, anemia, does prevail here. Why? The causes for the malnutrition that does prevail are both numerous and complex. Among these are: chronic infections, worry and mental strain, faulty dietary habits, ignorance as to what makes up an adequate diet, personal laziness, poverty, misleading food advertisements, denaturing of such staple and standard foods as flour (wheat, corn) and bread, possibly too great consumption of purified sugars and candy, waste of good foods, especially fruits and fats, etc.

Since man and his health constitute our most important natural resource, we must proceed without delay and with all the brains at our command to find better and more reliable methods to diagnose the signs and symptoms of *incipient dietary deficiencies*. Such knowledge will give us a clearer understanding of what constitutes an optimum diet for optimum health, so far as health is determined by diet alone. This, it seems to me, is a primary charge on the science of medicine, the science of biology, the science of chemistry. But we who labor in these fields will proceed faster along these lines, if we are encouraged by an understanding of the urgency and the difficulties in the problem and the cash cost of its solution on the part of all citizens.

Pending this greater scientific understanding as to human food needs for optimum health, these important things can and should be done now: (a) cleanse our present food and nutrition education of all fads, of all selfish commercial and myopic political propaganda; and (b) move our nutrition education from the ivory tower down to comprehension and appreciation of the common man. We have the brains and the cash to do it. Have we the will to carry on this hard task, when a possible superior health for all is the only goal, the only reward? I wonder.

NAVAJO SOCIAL ORGANIZATION AND LAND USE ADJUSTMENT

By E. R. FRYER

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THE recent history of the Navajo people began eight years ago. Then, there was depression and drought. Wool and livestock prices had sunk to new lows. The demand for the semi-luxury items of Navajo rugs and silver had nearly vanished. The traders had extended credit to the limit of their resources.

Fortunately, evictions, soup lines and bread riots passed them by, but the vicissitudes of the Navajo were not simply those of drought and depression. There were other and equally serious problems. For many years the range lands had been heavily overburdened with too many livestock. Disastrous erosion and unbelievable losses of life-giving top soil were the inevitable results. The population had been increasing so rapidly that the density was four times greater than comparable white occupied areas. Poverty was endemic.

The fact that the Navajo people faced environmental and economic destitution does not in itself make the Navajo problem unique. There are many such places in the world. The uniqueness arises from the fact that the Navajo country is a compact geographical unit held in the common ownership of the tribe—an area inhabited by the largest aboriginal cultural minority in the United States.

The Navajos are a distinct cultural group. Racially, linguistically, culturally, they stand apart from all other peoples except the Apaches and a few scattered Athabascan tribes in Northwestern Canada and Alaska. They differ from most other American minority groups in that they have not been in the stream of Euro-American culture.

This complex demanded an advance to a new frontier of thinking. There was a necessity for the application of knowledge, much of which had been theoretical and academic, to urgent and practical problems. There was the basic problem of relating the analyses of the physical and social disciplines. Administration planning and execution of plans had to be synthesized.

The government faced its problem courageously. It was one which might not have become such a festering economic sore had realistic, social and economic planning and administrative action earlier replaced timid paternalism. The government first reorganized its Navajo administrative structure. The six separate administrative jurisdictions that divided the Navajo country were eliminated. This confused and conflicting pattern was replaced by a centralized administrative authority. The many functions of two departments of the government were pooled into the Navajo Service and made directly responsible to the Commissioner of Indian Affairs.

It would be too lengthy here to recount all the steps and missteps, the advances and mistakes, the achievements and disappointments. Every advance in thinking marked an advance in administrative action. There still remains much to be done for the land and the people, but from the present vantage point it is possible to look back and view dispassionately the administrative and conceptual structure that has been built.

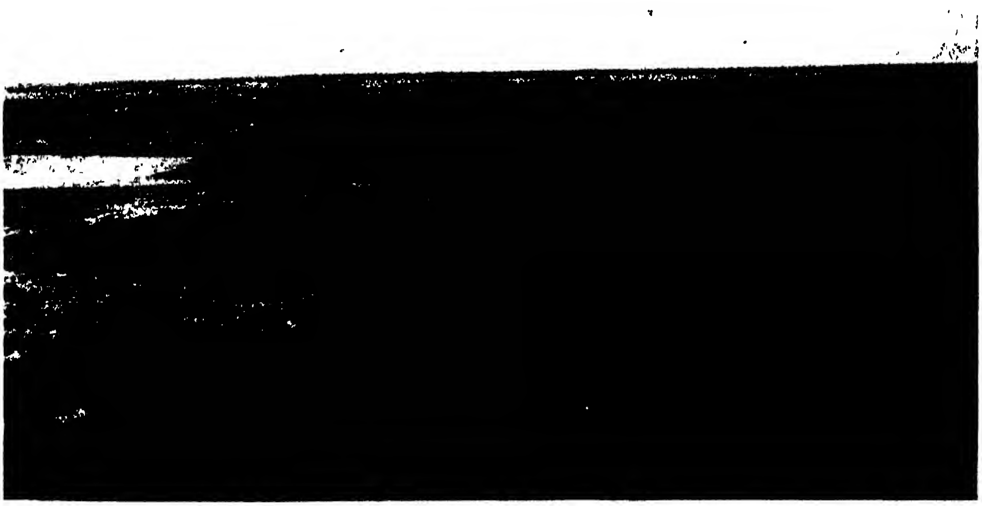
Basic to planning and administration in the Navajo country has been the concept of interdependence. There can be

THE TRUE DESERT—ONE OF THE NAVAJO ENVIRONMENTAL REGIONS
ABOUT FIFTY-FIVE PER CENT. OF THE RESERVATION CONSISTS OF DESERT LAND.

no realistic separation of social organization from erosion, poverty or population increase. The intricate web of relationships that bind person to person, whether in the family or in larger social units, manifests itself in the pattern of livestock ownership and range use.

The desperate efforts of a people, with a simple technology, to fill their bellies and clothe themselves and their children may produce a dust bowl. The spiritual values of a people who dignify the heavens and the earth as living beings may place barriers in the way of doing what to us appears reasonable and practical. The values, aptitudes and mechanical habits of the people may hasten or retard conservation and human rehabilitation.

The concept of interdependence is not



THE STEPPE—ONE OF THE NAVAJO ENVIRONMENTAL REGIONS
THE STEPPE REGION INCLUDES HIGH PLAINS, MESAS AND THE LOWER SLOPES OF MOUNTAINS.

THE MOUNTAINS—ANOTHER OF THE NAVAJO ENVIRONMENTAL REGIONS
THIS LAND IS SUITABLE FOR FARMING, SUMMER GRAZING AND FUEL AND LUMBER PRODUCTION.

new to science. The physicists use it, the ecologists and social anthropologists use it in the biological and cultural worlds. Basically, the concepts of these last two disciplines are similar and through them the Navajo Service was able to close the gulf which separates the physical and social sciences. The methodology was that of science. The government used the services of range and livestock technicians, engineers, agronomists, soil technicians, biologists, foresters and social anthropologists. Factual material was sometimes too generalized for planning purposes. It was only when the difference between mere inventories and the information needed for specific planning was realized that lost motion was eliminated.

Basically, the problem of "how" was the meshing of objectives with the values and social organization of the Navajo. Failing that, autocracy was left. The government could have been more authoritarian, but the facts on social organization indicated that the desired objectives could be achieved differently.

From this very generalized view of the problem let us now examine some details of the country and people.

The Navajo reservation with its 16,000,000 acres and 50,000 inhabitants is a portion of the semi-arid Colorado plateau. It is a region of rolling grasslands, shrub-covered valleys, wooded and forested mesas and mountains, cut by deep canyons. Through it all are wide expanses of barren and inaccessible areas. The two factors determining land base, relief and climate, are such that the balance of land stability is uniquely precarious. In such an environment production is limited. It can continuously support a human population only if intensities of land use are carefully controlled and technologies constantly improved.

For the past two hundred years the Navajo has been a sheep man with only supplementary dependence on farming and the sale of his rugs and jewelry, but before the introduction of livestock by the Spaniards and before trading had reached its present high state of development, the Navajos possessed a simpler economy. They farmed, gathered seeds and roots and hunted wild game.

The introduction of livestock permitted and forced seasonal migration of the people. The direction and tempo of this migration and expansion was influenced by the rapid increase of the population and the presence of external pressures. The major external historical factors limiting Navajo expansion was the establishment of the reservation boundaries and the encirclement by white settlers.

Not so many years ago they were able to lessen local pressures by internal adjustments. For many years, as range conditions declined in one area, it was possible for families to take their herds and move to new areas either unoccupied or not as intensively utilized.

Navajo economy is a function of environment. With the simple technology it could not be otherwise. The environment does not permit a great diversity of livelihood activities. Technologies introduced in recent years, as complicated irrigation systems, have broadened the economy. Fundamentally, however, Navajos or any other people must live within the framework of their physical world.

The Navajo country contains three distinctive aboriginal and environmental regions and a fourth, which is manmade. These regions are defined by parallel differences in elevations, temperature, rainfall and the availability of water for irrigation purposes. In each region conditions have given rise to characteristic adaptations in social organization and economy.

The largest region is true desert. It includes about 55 per cent. of the reservation. It is confined generally to the low plains, mesas and valleys below elevations of 6,500 feet. It is the warmest and driest portion of the reservation, with little grass and shrub vegetation and widely scattered watering places. It is the area of predominate dependence upon livestock.

In this desert region the population is sparse and the extended family group is the characteristic social unit. These large family groups are stable aggregates of population. They are interrelated with similar family groups residing in contiguous country. Marriage is frequently polygynous. Authority is definitely crystallized in the male head of the group, who has some of the characteristics of a minor patriarch.

Each group has one or more bands of sheep, cattle and always horses. Daily and seasonal livestock movements are very extensive for purposes of utilizing forage and securing water. Farming, if practiced at all, is on small favorably located places where seasonal floods spill waters over alluvial fans. The deficiency in production of needed vegetable foods is met by selling or trading livestock to traders or other Navajos in exchange for needed commodities.

The steppe is the second environmental area. It covers about 23 per cent. of the reservation. It includes high plains, mesas and the lower slopes of mountains between elevations of 6,500 and 7,500 feet. The climate is more favorable than the desert. The general resistance of steppe lands to erosion is greater than desert and it is capable of supporting larger concentrations of people.

The economy of the people living in the steppe country is a dual dependence on livestock and farming. The sheep are operated in small-sized bands with one band to each family. The movements of people and livestock are seasonal and nearly always circumscribed within limited community areas. Where seasonal movement occurs it is to utilize favorable areas for grazing and wood during winter and for farming purposes during the summer.

Although the relative density of population is greater than in the desert region there is not the same tendency towards clustering of families. One or two but seldom more families live in

THE MAN-MADE NAVAJO ENVIRONMENTAL REGION—IRRIGATED FARM LAND

adjoining hogans. The family groups as mechanisms for cooperative efforts are smaller, but in compensation there is a better-developed community organization.

The principal difference between the third, or mountain region, and the steppe country is in climate and vegetation. It is a relatively small area including about 8 per cent. of the reservation and is restricted to the mountains above elevations of 7,500 feet. The climate is relatively moist and cool. Water is abundant in many permanent streams and springs. The vegetation consists of coniferous forest with oak undergrowth and open parks of grassland. The land is suitable for short-season dry farming, for summer grazing, fuel and lumber production. The economy and social organization varies only in degree from the steppe. Here is found the same dual dependence on agriculture and livestock.

The fourth environmental region is a product of man's technological abilities. In this region the construction of complicated irrigation systems has changed the environment from desert or steppe to an area of fruitful farm lands. It is the area of a characteristic farm economy. The Navajo people who occupy these areas are farmers in every sense of the word. They live on or near their farms the year around. The individual family is the characteristic unit, although for purposes of cooperative farming, groups of families sometimes band together to perform the more difficult tasks. The population is dense and monogamy is the characteristic form of marriage. Acculturation is much more advanced.

Because of the concentration of population and other factors, these man-made environmental regions have become favored places for the location of administrative, educational and hospital facilities.

The critical problem of overpopulation and its attendant evils can be solved for the Navajo people by using the advanced technology of irrigated agriculture.

To meet the ever-growing need for more and more land for this ever-increasing tribe, two great opportunities other than minor projects within the reservation present themselves.

First, the colonization of Navajos on the Colorado River Project, now under construction, is not outside the realm of possibility. Here, 100,000 acres of rich river-bottom lands are being brought under irrigation by virtue of the Colorado River Dam. Part of the justification for the project was the hope that it might be used to resettle landless Navajos. It will not be easy for these people to pull their deep roots from Navajo soil but if economic pressure became great enough and land offers made which are attractive enough, Navajos without land or livestock can, in time be induced to accept land on the Colorado River.

The second agricultural possibility is the so-called "Turley Project" on the San Juan River. This, or a similar development on the San Juan, would make use of New Mexico's water quota under the Colorado River Compact and would place approximately 40,000 acres of Indian land under irrigation. This would be a tremendously expensive project, estimated to involve an expenditure of over $50,000,000. It probably is not justifiable for commercial agriculture, but it can be justified for subsistence farming. This project would irrigate a larger area of White lands than Indian.

Navajo technology and environment exhibit a fundamental interdependence. Environmental regions have effected the way in which Navajos relate themselves to each other; but environment does not rigorously dictate the customs or groupings of a people. Among all Navajos there is a basic cultural similarity, irrespective of the economy or environment. An understanding of these sociological

NAVAJO FAMILY GROUP AT THE HOGAN OF FRANK CATRON

NEAR TOHATCHI, NEW MEXICO. NOT INFREQUENTLY LARGE FAMILY GROUPS LIVE IN ONE HOGAN.

NAVAJO GIRLS CARDING AND SPINNING WOOL FOR WEAVING

similarities is basic to an understanding of the total problem.

The study of Navajo social organization reveals that there are three major social groupings, each of which varies in size, characteristics and functions. Each social grouping has its own characteristic structure and leadership. Each group is capable of filling specific needs and meeting the constantly recurring greater or lesser crises of life. The daily, seasonal or yearly events are faced not by independent individuals, but by persons who carry a common language and similar customs, and who have established habitual patterns of accomplishment and working together for mutual benefit. Each social grouping has its own emphasis in the environment in which it is found.

Basic to all Navajo social organization is the family. The Navajo family is that social unit which comprises all those persons living within one hogan. It may include but two persons, a woman and her husband, although the characteristic family group includes children and in some instances grandparents or even other relatives.

The organization of activity by which the family fills its needs is reflected in the division of labor on the basis of status, sex and age. The father and husband is the nominal head. The woman's role as mother and wife is limited compared to that of her husband. The hogan and its vicinity represents her locale of action. She is responsible for the preparation, serving and cooking of food; for the cleanliness of the hogan and her children; for making the clothing and for the general comfort of members of her family. She is the weaver and seller of rugs and her economic contribution to the family can not be overemphasized, but she is equally competent in the care of the sheep and assists her husband in the light work in the fields when the necessity arises.

FOUR NAVAJOS PROUDLY DISPLAY THEIR SHEEP
BETTER MANAGEMENT METHODS HAVE INCREASED THE PRODUCTION AND QUALITY OF NAVAJO WOOL.

The Navajo family can be viewed as an interdependent group of persons residing in one hogan, meeting the immediate and daily needs of its component members. Adequate as this social unity is for most purposes, there are many activities and crises which are not met by the individual family but by groups of families in cooperative effort.

The creation of a new family unit by the marriage of two individuals is, in Navajo thinking, not the union of two separate individuals but the establishment of a relationship between two families. The negotiations, the exchange

of property, the religious and secular aspects of the marriage and the residence of the newly married pair emphasizes this fact.

Those ties which bind family to family by reason of either blood or marriage are rarely completely severed. These ties manifest themselves in many ways. The construction of a new hogan or corral; the shearing or dipping of the sheep, all calls forth the cooperative labor of the family group.

The family group then represents a group of families possessing common close ties by blood or marriage, resident in one locality under one leadership and manifesting structure in the cooperative sharing and common meeting of crises of a greater intensity than those facing the family.

The family and family group are common features of Navajo social organization, easily recognized and described. Less well-known and more difficult to observe, because its manifestations are less apparent, is what we may correctly designate the land use community.

This social and economic unit usually contains a number of family groups living in a contiguous area. The external limits of the area of use form the boundary separating the community from other land use communities which are comparable in function and internal structure. Historically these communities and their area of use have each remained relatively stable. Each land-use community can be identified with a specific area of country. The occupants lay claim to the country as their own on the basis of ancestral settlement and present use. It is because of the territorial and use characteristics that this social group has been called the land-use community. Cooperative community labor and leadership exhibits itself most often in general problems relating to range use and water, the development

A NAVAJO TRIBAL SAWMILL ON THE EDGE OF A LOG POND

ROUND-UP OF CULL HORSES FOR SALE AND REMOVAL FROM THE RANGE
OTHER RESERVATION HORSES WILL BE BETTER FED AFTER HORSES LIKE THESE ARE REMOVED.

of farm land and the presentation of a united front toward those who attempt to encroach upon the community rights.

The land use community as a mechanism for planning and administration has important implications. Through the recognition of community areas of the people residing in the community and of their activities, it is possible to indicate specific areas for administration planning. The same mechanisms of cohesion and direction operating within a community group will continue to operate where administration recognizes and manages land on a community basis.

Another factor which had a great influence on Navajo economy must be mentioned briefly: the institution of trading. Traders to the Navajo fill a unique place in Navajo economy. They buy nearly all the things the Navajos sell. They sell nearly all the things the Navajos buy. The trader is the arbiter of Navajo fashions. He creates new wants and desires. Through his system of credit and exchange he exerts an enormous influence on Navajo life. If he is an efficient and devoted humanist as well as a merchant, he is a force for great good, but if through indifference to the welfare of the people with whom he trades he descends to the level of mere profit-making he can impoverish whole communities. The trader has undoubtedly made his contribution to the Navajo problem.

A government with superficial attitudes toward its Indian charges and a blind devotion to soil conservation might have passed off the Navajo crisis as a simple one of erosion caused by too many sheep, cattle and horses. It might have accepted the reduction of livestock as a cure-all. In reality the problem was and is much more complex. Fundamentally, it was caused by the attempts of too many people confined to a limited area, schooled in the tradition of a one-crop livestock economy, to wrest a living from unfertile lands. It was caused by ever-increasing commercial wants that could be met only by producing more and more livestock. It was caused by a costly and inefficient system of distribut-

ing consumer goods. It was caused by an inability to understand and apply more advanced technologies. It was exaggerated to some extent by the blindness of government. These and many other causative factors reached a climax of severity in the drought of the 1930's.

There is general agreement as to the events that developed in the Navajo crisis. A clear-cut analysis has made possible a clear definition of the broad objectives. They are:

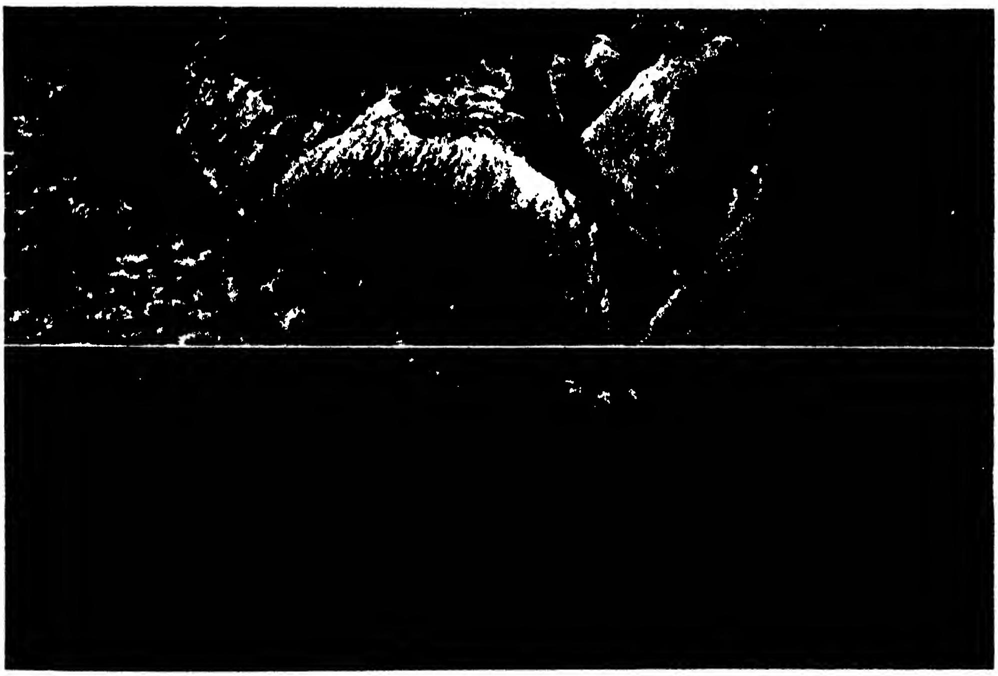
(1) Establishment of universal proper land use.
(2) Development of irrigated farmlands.
(3) Redistribution of the population for efficient utilization of resources.
(4) Strengthening the economic position of Navajos by means of extensive tribal and cooperative enterprises.
(5) Preservation of cultural integrity.

These objectives were formulated in a statement of policy on planning and administration, which follows:

(1) That the responsibility of the government is twofold:
  a. Conservation of natural resources.
  b. Improvement of human life.
  And that these two functions are complementary and interrelated.
(2) That the fundamental responsibility for land use, in a democracy, rests with the people who use the land and that though in the present case this responsibility is compromised by the trusteeship of the government and hence must conform to its policies, the ultimate goal shall be the furtherance of Navajo participation and responsibility in the management of their resources.
(3) That planning, here defined as the organization of knowledge for action, must be realistic in terms of the setting in which the action takes place. That realism connotes that life is lived dynamically within a functionally integrated set of relationships and on land. Fact-gathering and analysis may proceed piecemeal; overall planning to be intelligent, or what is more important, to be intelligible, must be done whole.
(4) That the Navajo area by reason of certain cultural and administrative consideration is a regional unit for planning, but that the problems therein considered have extra-area implications and that within the area local variations require special consideration. Treatment is regional within the definition of the word as a comprehensive and composite picture of man-land and man-man relationships in a defined area of use.
(5) That overall planning, though it must function at a highly generalized level, must avoid generalities and must be specific with regard to problems and conditions, the people they affect and the methods of treatment.
(6) That no plan can be final to the end of time or specific to the smallest detail. Flexibility and modifiability due to local conditions and changing times are essential to the effective utilization of plans.
(7) That day-to-day administration and direction of Indian affairs is the means by which


PICTURES "BEFORE" AND "AFTER" REVEGETATION
RANGE MANAGEMENT HAS PLANTS GROWING IN MANY AREAS FORMERLY BARREN OF GRASS.

FLOCKS OF SHEEP ON THE NAVAJO RANGE AT SUNSET
OVERSTOCKING ON THE RESERVATION HAS BEEN REMEDIED LARGELY BY THE SALE OF CULL ANIMALS.



EROSION CONTROL THROUGH RANGE MANAGEMENT
VEGETATION PREVENTS SHEET AND WIND EROSION SUCH AS THAT SHOWN IN THE TOP SECTION.

overall and long-time objectives are realized, that day-to-day needs of people must be met without losing sight of major purposes.

The past eight years have not been easy. There has been misunderstanding and opposition. There has been blundering. Popular writers have frequently misinterpreted the facts to the public. The wonder is not that there has been strife but that it has not been more severe. The situation demanded a revolutionary change in the technology and economy of an unsophisticated people. The Navajo have come through this crisis a stronger and more intelligent people.

There are many phenomena that can be expressed in quantitative terms. Much of the resurgent and revitalized Navajo behavior can not be thus expressed. The intense interest in improved livestock husbandry; the spreading interest in cooperatively owned trading posts; the farm, livestock and other associations; the responsible and recently developed optimistic tenor of meeting with leaders, are but manifestations of the strengthening of the Navajo's belief in his ability to cope successfully with the future.

Significant, concrete forward steps have been made in all the major phases of land use. Plant cover is almost universally improved. Areas formerly barren of grass cover are now in various stages of recovery with plant succession moving definitely in advanced climatic stages. Although gully erosion and silt production are still high, sheet and wind erosion have been measurably reduced.

The range livestock industry has been placed on a firm foundation by a reduction of livestock numbers to carrying capacity, and livestock improvement has been correlated with the reduction in such a manner that increased income has more than kept pace with reduction in numbers.

The percentage of overstocking on the reservation as a whole has been brought down progressively from 100 per cent. in 1932 to 34 per cent. in 1937, and to less than 1 per cent. in 1941. All this reduction since 1935 has been achieved by the sale of cull animals and the removal of powerful Navajo commercial operators to range lands outside the reservation.

The rapid expansion and successful settlement of farm land has given many Navajos security where before their existence and dependence on submarginal livestock or farming was precarious.

There has been a great expansion of cooperative enterprises. For many the tribe has used its own monies. These enterprises include an important lumbering industry; tribal flour mill; cannery; nursery, and farming enterprises, together with an important tribal project to buy and process cull animals for removal from the range, as well as a tribal project of considerable importance for the purchasing and distribution to the poorer people highly improved rams. A fund is now available for Navajo arts and crafts; to increase the production of salable handicraft, and for finding new and heretofore unreached markets. Navajo-owned cooperative trading posts are now in operation. Others are now in the process of organization. These Navajo-owned stores are operated on a non-profit basis. In their locality they are becoming the center of all community activities.

Navajo leaders are assuming objective progressive attitudes towards the many problems still facing the people and the government. They are accepting as never before the criticisms, burdens and responsibilities that must be the lot of any true and strong leadership.

On the basis of present plans and procedures we may visualize the future of the country and people of the Navajo. It can never be a land of milk and honey. The rigorous environment holds a never-

INTERIOR OF MEXICAN SPRINGS COMMUNITY TRADING ASSOCIATION
COOPERATIVE TRADING TAKES PLACE AT THIS POST IN MEXICAN SPRINGS, NEW MEXICO.

LOOKING TOWARD THE NAVAJO TRIBAL COUNCIL HOUSE
AT THE NAVAJO CENTRAL AGENCY, WINDOW ROCK, ARIZONA, WHICH WAS ESTABLISHED IN 1935.

INTERIOR OF THE NAVAJO TRIBAL CANNERY AT MANYFARMS, ARIZONA

ending challenge to man. But we know that the range is healthier than for many years. The livestock industry is fast approaching a level of high efficiency. Most young people must now turn to newly developed irrigated land for their livelihood. The land-use community will continue to be a responsible planning and administrative unit.

The future which most Navajos ardently wish for themselves and their children is the status of responsible, self-respecting, self-supporting citizens. Many minority peoples have been shattered by a too violent contact with an aggressive foreign people. The Navajos are not likely to suffer that unfortunate fate since the economic basis of cultural expression has been used by the government to strengthen the whole people.

The Navajos have learned in a decade a vast amount of the technological knowledge that Euro-American culture required centuries to build. They still do not understand the reason for many things they do, but find the results convincing.

The barriers of technological differences are being gradually removed. The Navajo farmer and stockman and his white neighbor are going through a common experience and from that comes common understanding.

The pattern of Navajo administration and planning is applicable to problem peoples wherever they may be. Through organization, direction and purpose the separate scientific disciplines have been integrated and findings converted to the level of action. A framework of administration and planning in full recognition of the total problem has been developed. The most complicated problems have been met through recognition of the many facets of a dynamic situation.

The need of total planning for other areas of the world is all too apparent if our democratic forms are to survive.

SOME GEOGRAPHIC ASPECTS OF LIMNOLOGY

By Dr. EDWARD S. DEEVEY, JR.
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THE lakes of the world do not bulk large on the map of the world or even on the maps of the continents. In some regions, of course, lakes dominate the landscape; yet in one of these places, Vilas County, Wisconsin, only about 15 per cent. of the area is under water, although the proportion in some parts of Finland and Minnesota is probably a little larger. South of the limits formerly reached by the great continental ice sheets lakes are very scarce and, aside from those formed by man, they may be almost wholly lacking in many states, such as Virginia and the Carolinas.

One must not judge the geographic importance of a feature by its areal extent, however. Gold mines and good harbors are even scarcer than lakes. I know of no lake comparable to a gold mine, unless some of the lakes of petroleum in California may be admitted to the comparison. I wish merely to draw attention to the fact that limnology, the study of lakes, is a geographic science. "To them that have shall be given," and to the modern geographers, who already have cast irredentist glances at geology, meteorology, oceanography, economics, anthropology and a host of other subjects, I make a present of still another "ology."

The question of the origin of lake basins is one of some geographic interest; the ecologist must also concern himself with the matter, since the origin usually determines the shape of the lake, and thus the hydrographic conditions and the nature of the biota. The biological history and to some extent the chemistry of the lake may also be bound up with its method of formation. The principal methods may be listed as follows:

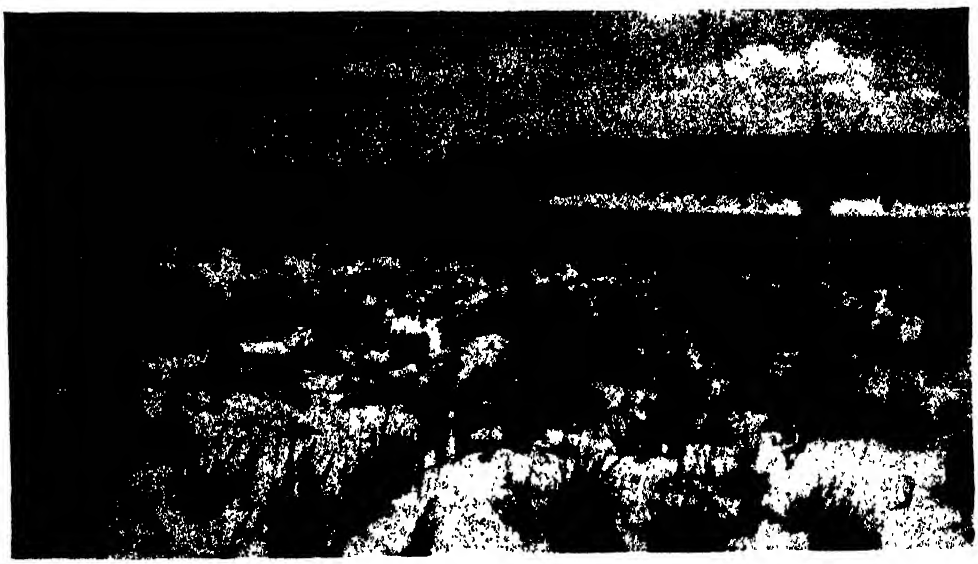


FIG. 1. SALT FLAT, AN EXTENSIVE PLAYA IN THE SALT BASIN
HUDSPETH COUNTY, TEXAS. THE BASIN IS A FAULT VALLEY, OR GRABEN, THE WESTERN SCARP (DIABLO PLATEAU) IS VISIBLE IN THE DISTANCE.

Archiv für Hydrobiologie

FIG. 2. MAP OF THE LAKE CHRISSIE DISTRICT, TRANSVAAL

SHOWING NUMEROUS SUBCIRCULAR PANS SCOOPED BY THE WIND IN AN ARID CLIMATE. DUE TO AN INCREASE IN RAINFALL THE PANS ARE NOW TEMPORARY OR PERMANENT LAKES.

1. Faulting and other structural changes
2. Wind action
   a. Deflation basins
   b. Lakes between dunes
3. Glacial action
   a. Dams formed by glaciers or their moraines
   b. Excavation by ice (cirques and troughs)
   c. Melting of blocks of ice embedded in outwash (kettles)
4. Fluviatile action
   a. Dams formed by levees
   b. Ox-bows
5. Solution
   a. Limestone sinks
   b. Depressions formed by solution of subterranean salt deposits
6. Volcanic action
   a. Caldera lakes
   b. Dams formed by lava flows
7. Organisms
   a. Basins eroded by ungulates (buffalo wallows)
   b. Basins dammed by beavers
8. Landslides
9. Meteorites

By way of summary of the geography of lake basins, one may notice, first, that lakes are generally by-products of processes resulting in physiographically youthful landscapes, and second, that lake-forming processes tend to be geographically restricted, so that we have "lake districts," characterized by lakes of one or two types.

If the existence of lakes is subject to geographic influences, their characteristics are equally so. The most important of these influences may be grouped under two headings, climate and lithology. Relatively little is known about the climatic factor in limnology; most of the world's limnologists live in the humid temperate regions of North America and western Europe, and those who have ventured out of this supposedly "ideal" climate into the tropics, high mountains, the Arctic or deserts, have been hampered by lack of equipment, adequate laboratory facilities and time. Most of our information about tropical lakes comes from the work

of the German Sunda Islands Expedition, and of Worthington and his colleagues on the Cambridge Expedition to the East African Lakes; for mountains we have the studies of Steinböck, Pesta and Leutelt-Kipke in the Alps, Hutchinson in the Himalayas, and very recently Pennak in the Colorado Rockies; desert lakes have been chiefly explored by Gauthièr in the Sahara and by Hutchinson in South Africa and Nevada; no serious limnology has ever been done in the Arctic or Antarctic.

I shall not attempt to discuss the influence of the temperature element of climate on lakes of different latitudes and altitudes; to do so would lead us too far into physical questions for the purposes of this paper. The rainfall element requires some attention, particularly as the expression "desert lake" sounds like a contradiction in terms to the average person. A true desert, of course, contains neither rivers nor lakes, but true deserts are comparatively rare. Most of the countries popularly called "deserts" are regions of *interior drainage*, in which more or less permanent rivers flow into more or less permanent lakes, but do not reach the sea.

As the lakes of these regions usually lack outlets, they act as gigantic evaporating pans, accumulating the salts delivered by rivers and ground water. Yet in spite of a relatively long time of accumulation, the concentration of electrolytes seldom approaches saturation. This is evidently because the arid lake districts are transitional, both geographically and climatically, between true deserts and moister regions. In dry periods the lakes dry up and their deposited salt blows away; in moister periods outlets form and the salts are washed out of the lakes to the sea. This susceptibility to slight climatic changes adds much charm and much exasperation to the study of desert lakes. Even the best maps tend to be unreliable, and mirages add extra zest to the life of the limnologist, who may not have suspected before his first trip to a desert that even slightly moist clay can reflect the surrounding mountains.

As a result of excessive concentration of electrolytes the lakes of arid regions

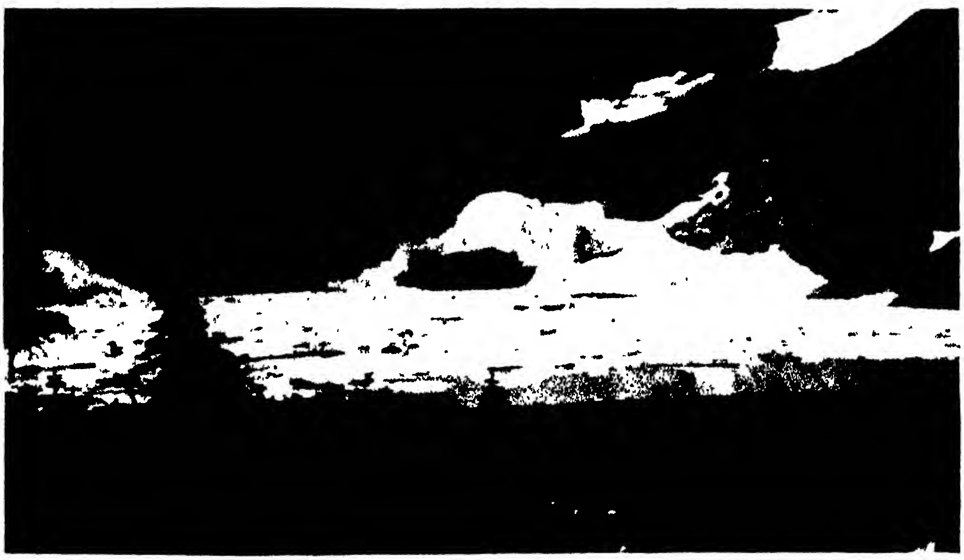


FIG. 3. ICEBERG LAKE

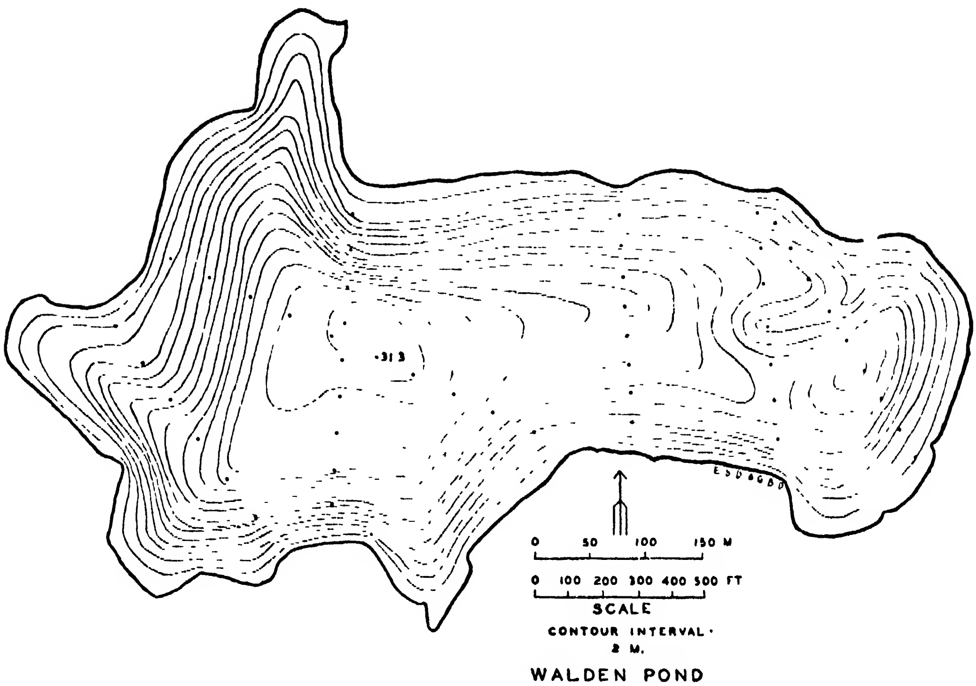
A CIRQUE LAKE NEAR MANY GLACIER, GLACIER NATIONAL PARK, MONTANA.

have a very select fauna and flora, consisting in extreme cases of one species of animal, the most familiar being the brine shrimp, Artemia. Often animals are absent, and the plankton is composed of plants alone. But as phosphorus tends to accumulate along with the other minerals, such lakes are very fertile, and the biota is usually rich in individuals.

Aside from the elements of climate, another group of geographic factors determines the character of lakes. This is the group collectively known as lithologic. We can see the operation of lithology more clearly in humid temperate regions, where climate can be assumed to be relatively uniform over wide areas. One lake may be rich in black bass because it has stony shores and lots of crayfish, another may be rich in crappie because it has shallow mud bottoms with weed beds abounding in insect life, and a third may support lake trout and salmon because there is a large reservoir of cold, well-oxygenated water in the depths into which those species can retreat in summer. But of course animals do not create food; they merely transform it, and in the final analysis the total quantity of life that a lake can contain depends on the chlorophyll-bearing members of the plant kingdom, which synthesize organic matter from inorganic materials, using the energy of sunlight. These plants in turn are dependent on certain inorganic substances. There is always plenty of water about in a lake, and there is usually plenty of carbon dioxide; but most of the elements of the periodic table are essential to the proper growth of some organism or other, and it will be obvious that the element which is present in smallest amount in nature in proportion to the needs of organisms will become a limiting factor or bottleneck. This element in the great majority of cases is phosphorus. Nitrogen may also act as a limiting factor, but of course the air is four fifths nitrogen, and provided certain bacteria are present either in

Ecological Monographs

FIG. 4. LINSLEY POND, NORTH BRANFORD, CONN., A TYPICAL KETTLE.



Quarterly Review of Biology

FIG. 5. BATHYMETRIC MAP OF WALDEN POND, CONCORD, MASSACHUSETTS SHOWING THE STEEP BANKS CHARACTERISTIC OF KETTLES.

the lake or in the surrounding soil, the atmospheric nitrogen can be transformed into a form which can be used by plants.

As a result of the knowledge of limiting factors in plant growth, when we find that lakes of one area are rich in all forms of life, from microscopic free-floating algae or phytoplankton, up through small animals (zooplankton) that graze on the algae to fish and other large animals that eat the small ones, while the lakes of another area are poor in all departments, we need not blame the fisherman or a mild Labor Day week-end or the niggardly stocking policy of the State Fish and Game Department. Nor, as ecologists seeking limiting factors, do we need to examine the whole periodic table for the explanation; we immediately suspect phosphorus. Some rocks are high in this element, others are low, and just as this unequal distribution is reflected in the fertility of the agricultural soils derived from the rocks, the productivity of lakes is governed by the lithologic factor. At any rate, this appears to be the reason why northern Germany and the region around Madison, Wisconsin, are very fertile lake districts, while northwestern Wisconsin, the highlands of Connecticut and parts of Japan are not. Even within the borders of a state as small as Connecticut we can see this factor operating, for there is a low-lying belt of soluble sedimentary rocks cutting across the highlands, which are composed of gneisses and schists and are probably poor in phosphorus. In the lowland lakes the phosphorus content of the water *and* the quantity of phytoplankton are above average, while in the highland lakes the phosphorus and plankton are below average, with some minor exceptions (Fig. 6).

So far we have been considering, from a rather special point of view, the lakes

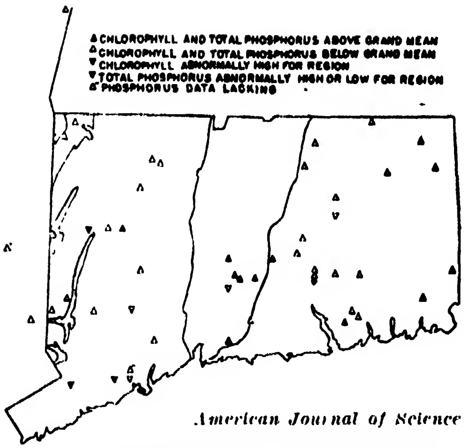


FIG. 6. PHOSPHORUS CHLOROPHYLL DISTRIBUTION IN FORTY-NINE CONNECTICUT AND NEW YORK LAKES. THE IRREGULAR NORTH SOUTH LINES ENCLOSE THE CENTRAL LOWLAND OF SEDIMENTARY AND IGNEOUS ROCKS. THE HIGHLANDS ARE COMPOSED OF METAMORPHIC ROCKS, EXCEPT IN THE DOTTED AREAS, WHICH ARE COMPOSED OF STOCKBRIDGE MARBLE.

of the world as we see them to-day. But no geographer can afford to forget that the present-day face of the earth is, as it were, a single frame in a continuous moving picture film. Physiography is constantly evolving under the impetus of forces set in motion long ago, the wearing down of continents and the filling up of basins, the shearings and crackings of the earth's restless crust, and the climatic conditions brought into being by the effect of land and sea on the circulation of the atmosphere. The form and characteristics of lakes, indeed their very existence, are naturally subject to the same forces, and the limnologist must reckon with changes that have taken place in the recent and sometimes in the more distant past. In fact, it is in this field of historical limnology that the biologist can contribute most effectively to the broad science of geography.

The last important epoch in the earth's history, and therefore the one about which we have the most information, was the Pleistocene (meaning "most recent") or Ice Age. The whole span of this epoch was probably not more than a million years, a relatively short section of the recorded age of the earth. During this time, as every one knows, great ice sheets formed at high latitudes and crept down the continents to latitudes as low as 40° in the northern hemisphere; several such advances, separated by partial or nearly complete retreats, are known to have taken place, and at approximately the same time local glaciers formed on high mountains, even within the equatorial zone, and sent arms of ice down the valleys into the plains below. But the startling climatic and physiographic changes wrought during the Pleistocene were not confined to the regions actually chilled or eroded by ice. Not only did the oceans rise and fall as more and less of the earth's supply of water was alternately imprisoned and released by the ice masses; in most parts of the world the climate was appreciably moister during periods of glacial advance and drier during interglacial ages. The effects of these climatic changes are especially well seen around many of the lakes of unglaciated regions, where high beaches and shore-line features record lake levels much higher than those of to-day. The Great Salt Lake, for example, large as it is, is a mere shadow of its former self, Lake Bonneville, which filled a number of now-dry basins to a maximum depth of more than a thousand feet, and had an outlet to the north. Another large lake, Lake Lahontan, occupied several adjacent basins of western Nevada, but as the climate became drier it shrank to a few saline pools such as Pyramid and Winnemucca Lakes, of which at least one is still extensive enough to attract tourists from Reno with time on their hands. The periods of unusual moisture that permitted these great lakes to exist are called "pluvial periods," and there appear to have been at least two of them during the Pleistocene, corresponding roughly to the first

two and the second two glacial ages of cooler countries, and separated by an interpluvial, which in some places was one of intense aridity.

The detailed study of any of the great pluvial lakes is extremely fascinating, but I shall discuss only those of equatorial Africa, no longer called "darkest" except in Hollywood, for its dramatic Pleistocene history is the best known of any comparable area (Fig. 7). This history is made rather complicated by earth movements which occurred on a gigantic scale, and many details remain to be filled in; in particular the dates of many events are still uncertain, but fortunately, as the evolution of the topography of this region is intimately bound up with human prehistory, geographers and biologists have been able to enlist the very valuable services of the archeologists, who have corroborated many inferences and added much new information of their own.

During most of Cenozoic time the center of Africa was like an immense flat-topped dome. On this dome the principal river systems rose in a huge swampy area, through which their headwaters intercommunicated, and flowed radially to the sea. The fishes of all the river systems and their associated lakes thus had an opportunity to mingle, and even to-day we find that the genera of the Nile, Zambesi, Congo, etc., are the same for the most part, although the species are different. The rivers of Uganda flowed westward to the Congo. Toward the close of the Cenozoic, however, earth movements began to be felt; the first great change appears to have been the gradual sinking of part of the central dome to form the basin of Lake Victoria. This process resulted in the reversal of the Uganda rivers, which were then decanted into Lake Victoria. As the movements of the crust were intensified, immense faults were formed, and the great Rift Valleys were dropped down between the faults, the western Rift coming to lie athwart the Uganda rivers. This caused their western sections to be diverted again, but now the harassed water flowed into the Rift and made its way northward to the Nile. Intercommunicating lakes occupied the deeper portions of the Rift Valleys, and as the first pluvial period occurred about this time, these lakes were much deeper than to-day.

The connection of the Rift Valley lakes and Lake Victoria with the Nile drainage gave opportunity for aquatic animals to make their way from the Nile into the lakes, there to evolve into new species adjusted to different conditions but showing strong affinities with their Nile ancestors. But during the great interpluvial the climate was so arid that all the lakes, with the exception of Tanganyika and Nyasa, whose bottoms are below sea level, dried up, and the aquatic fauna was extinguished. A whole new colonization from the Nile took place during the second pluvial period, when

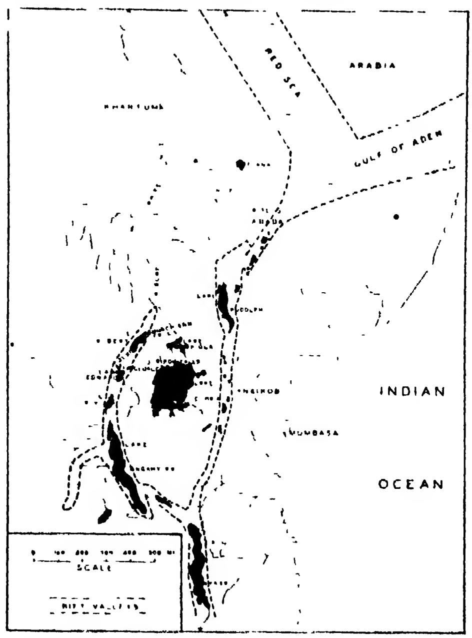


FIG. 7. EAST AND CENTRAL AFRICA SHOWING THE RIFT VALLEYS (ENCLOSED BY DASHED LINES).

the lakes reformed, and the species of the modern lakes still show affinities with those of the lower Nile. However, many interesting details have prevented a complete mixture and uniformity of species. For example, the Nile crocodile is now absent from Lake Edward, apparently because it has been unwilling to walk around the Semliki Falls through several miles of dense forest in order "to see what there is on the other side," as Worthington puts it; it is known to have been present during one of the pluvial periods, but was wiped out when Lake Edward dried up. As the crocodile has managed to get around the Ripon Falls into Lake Victoria, this lack of initiative seems surprising. To take another example, the fauna of Lake Rudolph is very like that of the Nile, although Rudolph is now quite saline and without outlet. An outlet to the Nile almost certainly existed during pluvial times, however, when the lake was about 475 feet deeper than to-day, and spilled out of the Rift Valley through a gorge.

Other differences in detail occur which are really striking, and they evidently stem from the fact that the colonization of the lakes was to a considerable extent accidental, depending on the species which happen to have got around such barriers as the Semliki, Murchison and Ripon Falls, and their subsequent evolution into new species. Thus of 111 species of fish found in Lake Victoria, 85 are endemic, that is, found nowhere else in the world, while in Lake Edward, 22 of the 38 species are endemic. The molluscs also show a high degree of endemism in the lakes.

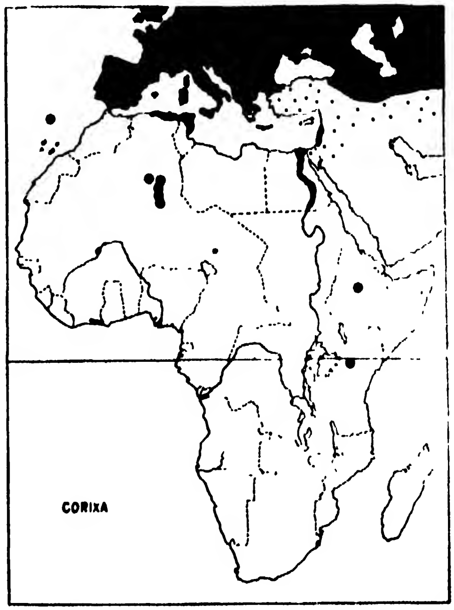
From the biological standpoint the most remarkable of the African lakes are Tanganyika and Nyasa, which alone are deep enough to have contained water continuously since before the Ice Age. They are true aquatic "lost worlds," with an exceedingly high proportion of their species restricted to them. In Tanganyika, which is much the better known of the two, in addition to the fish, of which 131 species, or 79 per cent., are endemic, there is a vast array of novelties, such as a group of spiny molluscs curiously resembling marine forms extinct since the Jurassic; this resemblance is now known to be superficial, and while the fauna of Tanganyika is old, it is not a survival from the Mesozoic. There are endemic species and even genera, among the insects, crustacea and several other invertebrate groups, and the fauna includes a remarkable fresh-water jellyfish, which, however, has recently been found elsewhere in Africa.

Parenthetically, I may remark that there are at least two other lakes comparable to Tanganyika in that they have led a continuous and rather isolated existence since the Tertiary, and in the exuberant evolution of peculiar species in their waters. The more extraordinary is Lake Baikal, in Siberia, and the other is Lake Ochrid, in the Balkans. Probably 90 per cent. of the animals of Baikal are found nowhere else, and a large proportion belong to genera which are also unique.

The effects of the pluvial periods were naturally not confined to equatorial Africa. Lakes expanded in the Sahara as well as in South Africa. In the Sahara several of the oases, such as Kharga and the Faiyum depression, held lakes during pluvial times, and as primitive man lived on their shores and on their dry bottoms when opportunity offered, archeology has been able to provide datings for the geologic events. One of the most interesting by-products of a moister Sahara was the leakage of European species of aquatic animals into equatorial Africa, as shown for example by the geographic distribution of several species of Corixa (Fig. 8), the water bugs known as "water boatmen."

A species whose present distribution

can not be accounted for by present conditions, but is clearly the product of conditions obtaining in the past, is called a "relict"; we speak of *Corixa mirandella* as a "pluvial relict," but other types of relict distribution are known. On the northern continents many species, both aquatic and terrestrial, show a distribution that is obviously related to glacial ages rather than to present climatic conditions, and these are "glacial relicts." In fact, there is good reason to believe that important readjustments are taking place in the ranges of animal and plant species all over the world to-day, simply because the time elapsed since glacial and pluvial ages has been too short for the attainment of equilibrium. The subject is one of immense geologic and geographic importance, but progress has been hampered by excessive departmentation; not only have geologists been ignorant of the work of students of animal and plant distribution, and *vice versa*, but authorities on the distribution of one animal group, say the beetles, have paid no attention to the work of experts on other groups, say the tree-frogs or the water-fleas.



Internationale Revue der gesamten Hydrobiologie und Hydrographie

FIG. 8. WATER-BUG DISTRIBUTION

GENUS CORIXA IN AFRICA AND EUROPE. DURING THE PLUVIAL PERIODS A MOISTER SAHARA EVIDENTLY ALLOWED SEVERAL SPECIES OF THIS GENUS TO "LEAK THROUGH."

Before concluding this survey of geographic limnology, I should like to consider some of the relations between limnology and human geography—some of the ways in which lakes as geographic units affect the distribution and culture of man. These relations are especially close and conspicuous in the case of primitive man. To be sure, important instances can be found in which lakes affect the welfare of the human race in its most "civilized" state; we hear much of the military strategy centering about Lake Ilmen and Lake Ladoga, and of Russia's Caspian Sea lifeline, and in densely populated countries like Central Europe and China, the annual fish crop of inland lakes is managed and harvested with scrupulous care, aquaculture being nearly as important as agriculture. To a smaller extent this is true of our own Great Lakes area. Admiral Horthy's title is not one of courtesy; the Hungarian Navy sails the shallow but extensive waters of Lake Balaton. And according to recent news reports a U. S. Navy hydroplane contrived to set itself down on a mirage in southern Texas. But these instances are bound to be exceptional if only because of the relatively small fraction of the earth's surface occupied by lakes. In many areas where lakes are most abundant, such as Wisconsin and Maine, their chief modern use is for recreation, in pursuit of which civilized man temporarily returns to the economic activities of his primitive ancestors, hunting and fishing.

The integral part played by lakes in the culture of primitive peoples is nowhere better illustrated than in the lake district of equatorial Africa. The shores of Lake Victoria and the other lakes

support numerous fishing villages, the people of which may have little in common except that they are black and adopt fishing as their chief means of livelihood. The type of boat constructed and the methods used to capture fish differ widely among the various tribes, depending partly on local conditions and available species of fish, but mostly on the independent evolution of methods by people of different racial stocks having relatively little contact with each other. Most of the methods used are highly ingenious and have not been improved upon by civilized man; they include seines, weirs, hand baskets, traps, hand lines, set lines, angling and a host of minor variants (Fig. 9). All of them

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FIG. 9. AFRICAN FISHING METHODS
Above: AN OBALALA OR TRAP OF REED FENCING AT THE SIDE OF A KEK ("WEIR"); THE MAN IS REMOVING THE CARP-LIKE NGEGE (*Tilapia*) WITH THE AID OF A CLASP-NET. *Below:* LIFTING THE BASKET TRAPS OF AN OSAGERU, OR FISH MAZE.

imply close study of the habits of the different species, and in fact it is axiomatic that primitive hunters and fishermen are very able naturalists. One of the most extraordinary methods of capture employed on Lake Albert makes use of the natural food chains of the lake, a phenomenon which did not receive adequate scientific attention until a few years ago (Fig. 10). The natives lower bundles of brush in about 30 feet of water, marking them with buoys. Each morning they haul them up, and extract the many tiny fish (Haplochromis) which worm their way in, seeking shelter. The Haplochromis are fixed to a hook and dangled overside on a pole, where they serve as bait for their natural enemy, the voracious tiger fish, a pickerel-like fish over a foot long. When caught, the tiger fish are then fixed to an enormous iron hook attached to a long rope. They are the bait for the real quarry, the gigantic Nile perch, which may reach a length of five feet and weigh two hundred pounds. If the Nile perch is too large to be boated at once, the line is made fast to the canoe and the fish allowed to play himself out over a distance of many miles.

The lakes of Africa are not only important for their fish and their water supply. Salt is being precipitated from some of the more concentrated waters, and serves as an important item of commerce among native tribes. Agricultural peoples living on an exclusively vegetable diet have an especially heavy demand for salt, and a tribe lucky enough to have a salt lake in its territory does not need to fish or hunt or practice agriculture, but maintains itself on the manufacture and sale of salt.

The Valley of Mexico is another region in which lakes played a great role in the culture of primitive people. Maudslay's map of the Valley at the time of the conquest in 1521 gives an impressive picture of the density of population

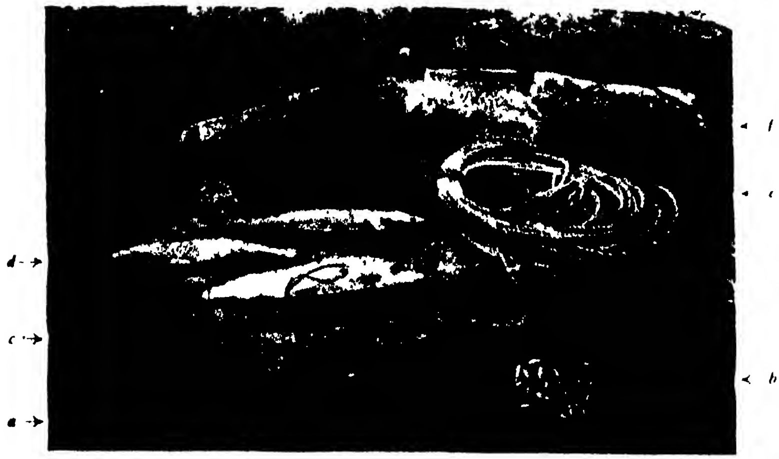

FIG. 10. BANYORO METHOD OF FISHING

MAKING USE OF THE NATURAL FOOD CHAIN OF LAKE ALBERT. (A) BUNDLE OF REEDS IN WHICH HAPLOCHROMIS IS CAPTURED; (B) HAPLOCHROMIS; (C) HOOKED POLE, BAITED WITH HAPLOCHROMIS, FOR CAPTURE OF TIGER FISH; (D) TIGER FISH; (E) ROPE AND HOOK, BAITED WITH TIGER FISH FOR CAPTURE OF NILE PERCH; (F) NILE PERCH.

around the lakes at that time. It is true that the extraordinary civilization of the Mexicans was made possible by commerce and by tribute levied on the people of the entire country, and was not wholly supported by the Valley itself. Nevertheless the lakes served the inhabitants in a variety of ways. The waters of the fresh lakes abounded in edible fish and a tasty salamander, the axolotl, and their shallow marginal areas were the seat of a flourishing agriculture maintained on chinampas, or floating truck gardens. In the salt lake of Texcoco immense swarms of water bugs were collected, the dried insects being used as food for birds, while the eggs were collected from the bottom and from brush piles placed in the water for the purpose, and made into an edible cake "like cheese," the source of which puzzled the conquerors. And it must not be forgotten that for centuries the lakes served as effective moats for the protection of the island communities, of which Tenochtitlan, now Mexico City, was the most important. Only through the consummate skill of a great military strategist did this advantage become a tragic liability, when Cortez seized the causeways, cut the aqueduct and turned the city into a death trap.

The great lakes of the Valley have now been drained, with the exception of the shrunken remnant of Texcoco and the tortuous passages between the chinampas of Xochimilco. Some idea of the original Mexican lake culture may still be obtained, however, at Lake Pátzcuaro, two hundred miles west of Mexico City in the country of the Tarascans, whose ancient capital, Tzintzuntzan, on the shore of the lake, always maintained its independence of the powerful Aztec empire to the east. Pátzcuaro is not the largest lake in Mexico, but it is unsurpassed for beauty and interest. The modern Tarascans, particularly those of the island community Janitzio, maintain a fishing culture which must resemble in many respects that of the Aztec lake villages. Two principal types of gear are used, the first, the chinchorro, being a seine as long as 300 meters, operated offshore from several dugout canoes, and

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FIG. 11. TARASCAN FISHERMEN
WITH DUGOUT CANOES AND BUTTERFLY NETS, LAGO DE PATZCUARO, MICHOACAN, MEXICO.

the second the mariposa, or butterfly net, shown in Fig. 11. Several types of native fishes are caught, mostly members of the family Cichlidae, the same family which has produced so many endemic species in the African lakes. Some of these are small and live in the upper water like sardines, while the celebrated Pátzcuaro "whitefish" is larger and lives in the weeds. In addition the large-mouth black bass of the United States has been acclimated, and is called by the natives "trucha," or trout. The lake, like several others of the western plateau, is apparently a residual descendant of a large pluvial lake, and since its isolation several endemic species have been evolved, including one of the Cichlid fishes and a large salamander, which is also eaten by the Indians.

Of course I have not yet mentioned the Neolithic lake dwellers of Europe, or the many other lake cultures known to archeology. A tabulation of these, if one could be made, would doubtless show that the wide, swampy, lake-dotted valley has served many times in the history of the human race as a focus of civilization; aside from the Valley of Mexico, other examples are the upper Rhine valley, the basin of Lake Titicaca, and possibly Glastonbury, the British Iron Age site. A recent case in point is the Vale of Kashmir, where, to judge from Hutchinson's account, the use of floating truck gardens parallels to a remarkable degree that at Xochimilco. But there is no need for me to belabor the point. I shall be content if I have indicated, by means of this brief summary, something of the position of limnology in the ever-widening sphere of the geographic sciences.

NOTE: The foregoing article leans heavily on the work and ideas of Professor G. Evelyn Hutchinson, and much of it has been shamelessly borrowed from his copyrighted "Notes on Limnology," still in mimeographed form. Another large fraction has been taken from the excellent non-technical account of "The Inland Waters of Africa," by S. and E. B. Worthington, including Figs. 9 and 10.

CRYSTALLINITY IN CELLULOSE ESTERS

By Dr. W. O. BAKER

CHEMICAL LABORATORIES, BELL TELEPHONE LABORATORIES

TOUGHNESS, strength and flexibility of plastics extensively applied in communications, aircraft, and as metal substitutes for the defense program are influenced by the arrangement of their giant molecules as well as their composition, according to recent investigations of Bell Telephone Laboratories. Plastics contain molecules thousands of times larger than those of water or gasoline and in most cases these molecules are very long and threadlike. Hence they are frequently called chain or polymer molecules. Derivatives of cellulose are among the most important polymers which can be readily formed into any desired shape, much as metals are cast. Cellulose is the principal constituent of cotton and woodpulp, and hence its derivatives relate to products of economic and strategic importance, easily produced in this country.

The present investigation concerns chiefly certain compounds of cellulose, such as cellulose acetate and cellulose butyrate. These are used for electrical insulation, moldings of apparatus, photographic film, airplane dopes and lacquers. It was desired to discover the fundamental properties which make these materials resistant to shock, bending, twisting and dimensional change. The studies were undertaken on a molecular scale rather than with the usual engineering tests, and the high magnification necessary was obtained by photographing x-ray beams after they passed through selected samples of the plastics. These photographs differ from ordinary x-ray shadow pictures in that they give diffraction patterns which can be measured to show distances between the molecules as small as a billionth of an inch, and also to indicate how the molecules are placed with respect to each other in the solid.

The samples studied were small, flat sections about one mm thick. This small size facilitates examination of special parts from moldings, and even thinner films from lacquers. The samples were rigidly mounted on a lead insert, Figure 2, so as to cover a small cylindrical hole through its center, which formed a tiny pipe through which x-rays were guided, from the tube where they are generated, to the sample. When this minute cylindrical beam of x-rays passes through the plastic, much of it expands into a cone because the regular layers of molecules have diffracted it. Actually, there are often many coaxial cones, whose axes are along the original, unbent beam. These cones have a common apex at the point where the x-ray beam leaves the sample on its way to the photographic plate. After three or four hours exposure they appear on the developed photographic film as circles and the degree of crystallinity in the sample is shown by the sharpness and the number of circles recorded.

In striking analogy to the behavior of metals, it was found that the cellulose esters could be quenched by cooling them rapidly from the molten state. The long polymer molecules were then found to be disordered with respect to each other; that is, given faces of the molecules did not all point in the same direction throughout portions of the solids, as would occur in crystals. Neighbors of a given molecule are quite randomly arranged although there is a tendency for sections of the chains to lie side by

side. They are like a company of soldiers drawn up in formation except that the men as a whole face in all directions, rather than just to the front. When these plastics are cooled slowly from the melt, however, much greater order occurs, and it is as though little squads of men through the company stood at attention facing the same way in a given squad, although all the squads as units do not face in the same direction. The molecules have a very ordered arrangement in local regions throughout the plastic.

When the molecules in the plastic have the maximum disorder, the material tends to be most soft and flexible and when they are most ordered, or crystallized the material is hardest and strongest, but sometimes brittle. These extremes are illustrated by gum rubber, for instance, in which the molecules are disordered, while in ice or sugar, which are brittle, they are almost perfectly ordered. Evidently a compromise between these extremes is most desirable for toughness and general industrial utility. The x-ray studies show that various amounts of order and disorder can be produced in a given cellulose plastic by the quenching or tempering treatment.

Two other methods of controlling the number of organized and disorganized molecules have been long used in the technology of cellulose plastics, as work-

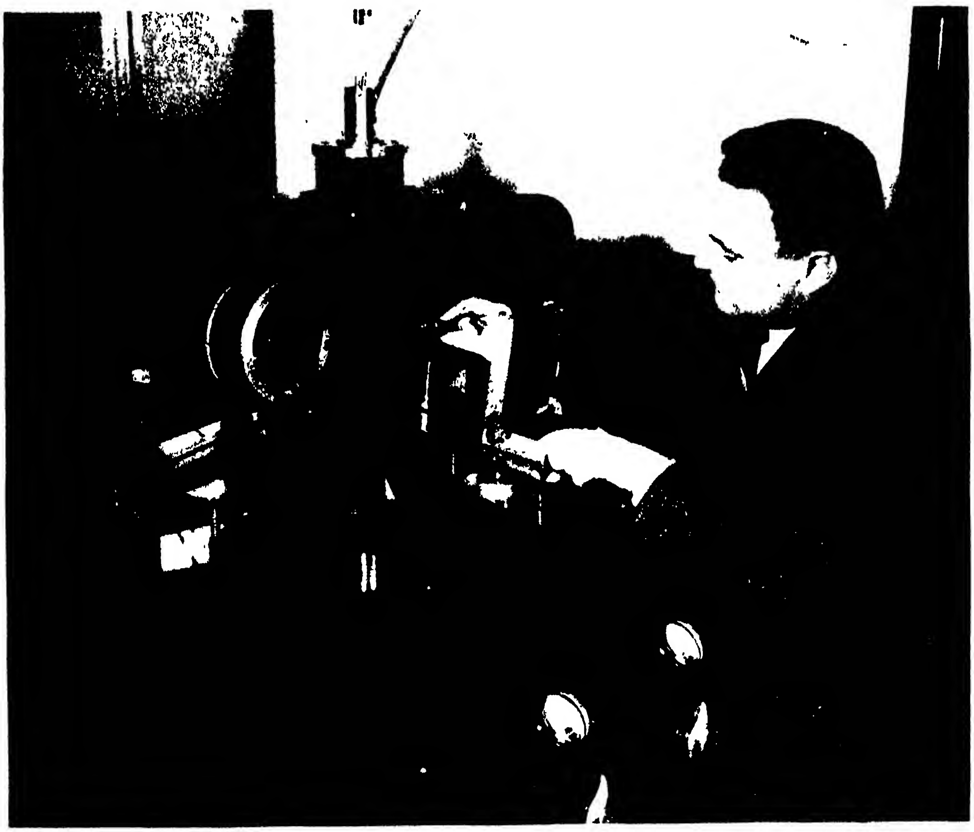

FIG. 1. X-RAY SPECTROMETER

FOR STUDYING THE CRYSTALLINE STRUCTURE OF MATERIALS. THE TUBE IS ENCLOSED IN A SHEET-LEAD HOUSING TO PROTECT THE OPERATOR FROM STRAY X-RADIATION.

ing procedures. The first is to control the shape of the cellulose ester molecules by the amount of the reaction and the nature of the substituting group so that they can only partially fit together to give an ordered array. By analogy, a few extremely fat men would cause the army squads to become locally disarranged, a desirable condition, at least in the plastic. The second, and this applies chiefly to lacquers such as airplane dopes and film formation, is selection of a particular solvent or mixture of solvents, which evaporates as the cellulose ester film dries. Various liquids were found to cause different amounts of molecular order in the resulting films. The analogy to the soldiers here is to imagine a company of them swimming about in a reservoir of water which is then drained so that the men settle toward the bottom. When they can finally stand there they may be found either disordered and facing in all directions or in intermediate degrees of organization, with some almost in parade formation. For the molecules, the degree of order in which the liquid leaves them has been found to depend largely on the nature of the liquid, and hence arises the technical importance of choosing the right solvents so that the films will not crack off flexing wires or vital airplane parts.

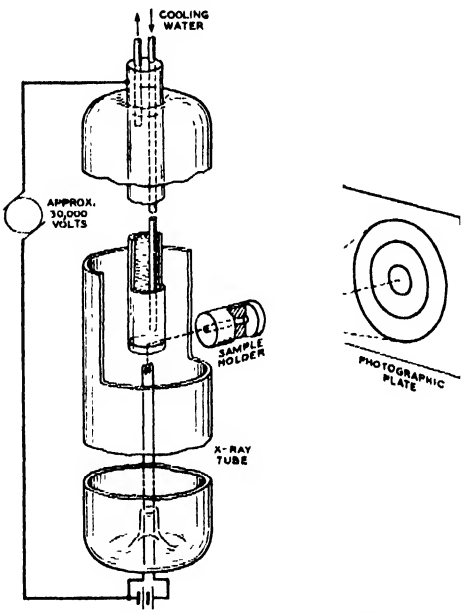

FIG. 2. X-RAY APPARATUS
IN X-RAY STUDIES OF THE CRYSTALLINITY OF CELLULOSE ESTERS A FINE STREAM OF THE RADIATION PASSES THROUGH THE SPECIMEN AND IS DIFFRACTED BY IT INTO A SERIES OF CONCENTRIC CONES WHOSE BASES ARE RECORDED AS CONCENTRIC CIRCLES ON A PHOTOGRAPHIC PLATE.

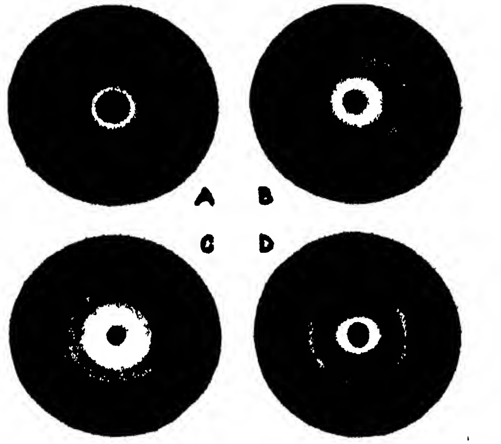

FIG. 3. CELLULOSE ESTER
X-RAY DIFFRACTION PATTERNS ARE SHOWN: (A) IN HIGHLY CRYSTALLINE CONDITION; (B) MOLECULARLY DISORDERED; (C) IN PARTIALLY CRYSTALLINE STATE, WHICH WAS OBTAINED BY ANNEALING THE SPECIMEN; (D) SIMILAR PARTIAL CRYSTALLINITY RESULTING FROM SOLVENT ACTION.

An interesting detail of the study was proof that sections of the plastic's molecules could move around and "come to attention" in ordered positions in the solid state. The molecules in solids are generally regarded as being fixed but it is now found that actually they undergo considerable torsional motion, under the influence of temperature. Thus, it was possible to anneal the quenched cellulose esters, and the x-ray patterns showed how this annealing process caused the chain molecules to take up ordered positions. This ability of portions of the molecules to move in plastic solids even at ordinary temperatures appears closely related to their plasticity and capacity to bend and return to the original form.

Edmond Halley

FROM A PORTRAIT BY M. DAHL IN THE POSSESSION OF THE ROYAL SOCIETY OF LONDON.

EDMOND HALLEY, 1656–1742

By Dr. N. T. BOBROVNIKOFF

DIRECTOR, PERKINS OBSERVATORY, OHIO WESLEYAN AND OHIO STATE UNIVERSITIES

EDMOND[1] HALLEY was born on November 8, 1656 (new style), at Haggerston in the parish of St. Leonard Shoreditch in the suburbs of London. His father was a prosperous business man, but subsequent losses greatly impaired his fortune. Nevertheless he gave his son an excellent education in St. Paul's School where young Halley became proficient in Latin, Greek, Hebrew, and mathematical sciences. At midsummer, 1673, Halley was admitted as a student of Queen's College, Oxford University. From this time on for some thirty years Halley's life was rich in events.

He published his first scientific paper on planetary orbits in the *Philosophical Transactions of the Royal Society* in 1676 when he was only 19 years of age. In November, 1676, he sailed for the Island of St. Helena in order to make observations of southern stars. He returned to Oxford in the fall of 1678 to receive the degree of Master of Arts. The usual formalities were dispensed with after King Charles II sent a letter to the university highly commending Halley for his work at St. Helena.

In the same year Halley was elected fellow of the Royal Society. He soon left London for a conference with Hevelius at Danzig concerning the best methods to be used in observations of the stars. It might seem strange to us, but Hevelius would not admit that telescopes were of any advantage in observing the positions of the stars. Halley tried to prove the advantage of the telescope, but apparently Hevelius would not change his opinion. Halley, however, developed a friendship with Hevelius and stayed in Danzig for two months. In December, 1680, he started on a trip to France and Italy, where he became acquainted with eminent scientists.

In 1682 soon after his return from Europe Halley married Mary Tooke, with whom he lived happily for 55 years until her death. Two daughters and one son were born to this marriage. At about this time Halley met Newton and formed a friendship that lasted as long as they both lived.

Between the years 1682 and 1696 Halley did not occupy any official position aside from being assistant secretary of the Royal Society. In 1684 Halley's father died under mysterious circumstances, and there was a litigation between Halley and his step-mother which very adversely affected Halley's financial status.

When Halley applied in 1691 for the Savilian professorship at Oxford, his orthodoxy[2] was questioned. Bishop Stillingfleet, who examined Halley, was not satisfied, and Dr. Gregory received the appointment.

[1] The correct spelling of the Christian name is Edmond not Edmund, although even Halley's contemporaries often used the latter spelling. There is no detailed biography of Halley. Some phases of his career would require considerable research in contemporary documents. In the preparation of this article, extensive use has been made of "Correspondence and Papers of Edmond Halley," arranged and edited by E. F. MacPike, Oxford, at the Clarendon Press, 1932.

[2] This point is not sufficiently appreciated by the modern historians of science. Whiston, the successor of Newton in Cambridge, was removed from his professorship and reduced to poverty on the charge of being Arian (*Phil. Trans. Roy. Soc.*, abridged, 6, 532, 1809). In the case of Halley there were other causes for the decline of his application, such as Flamsteed's animosity. Gregory certainly was not much better off than Halley in the matter of orthodoxy. There is a story about a Scot looking for Halley because he "would fain to see the man that has less religion than Dr. Gregory." (MacPike, *op. cit.*, p. 265.)

In March, 1696, Halley was appointed comptroller of the mint at Chester, an office which he held for about two years. At this time Peter the Great of Russia was in England, and Halley was introduced to him. Peter the Great conferred with him about the Russian navy and the development of sciences in that country and was so pleased with him that Halley was admitted "to the familiarity of his table."

In 1698 King William III appointed Halley commander of a ship, which bore the quaint name *Paramour Pink*, with orders to investigate the variation of the magnetic needle in the South Atlantic Ocean and to "call at His Majesty's Settlements in America, and make some observations there, in order to the better laying down in Longitudes and Latitudes of those places, and to attempt a discovery of what Lands lay to the South of the Western Ocean." Halley set out on his voyage on November 5, but on crossing the equator there was mutiny on the ship and Halley returned to England in June, 1699. According to the official letter of June 23, 1699, from Halley to Josiah Burchett, Secretary to the Admiralty, Halley's Lieutenant Harrison "was pleased so grossly to affront me, as to tell me before my Officers and Seamen on Deck . . . that I was not only incapable to take charge of the *Pink* but even of a Longboat; upon which I desired him to keep his Cabbin for that night, and for the future I would take the charge of the Shipp my self to shew him his mistake: and accordingly I have watcht in his steed ever since, and brought the Shipp well home from near the banks of Newfound Land, without the least assistance from him."[3]

Halley was evidently considered by the admiralty as a captain with full authority and not merely as a scientific observer. After the court martial of his lieutenant, Halley sailed again on board the same ship. The story of Halley's adventures is told by him in his letters to the admiralty. They throw much light on Halley's character as well as on conditions prevailing at sea in his time. On the first voyage Halley called at the Cape Verde Islands where the *Paramour Pink* was fired upon when it was taken for a pirate ship. After some adventures in Brazil the mutiny referred to above occurred. On the second voyage Halley called at Madeira, St. Helena, and Rio de Janeiro. From there he sailed to the latitude S 52 1/2° where he "fell in with great Islands of Ice, of soe incredible a hight and Magnitude that I scarce dare write my thoughts of it."[4] After the dangers of navigating among ice-fields, the ship finally reached the Islands of Tristan da Cunha and sailed back to St. Helena. From there Halley went to Trinidad and Pernambuco where he was nearly arrested by the British consul when he was suspected as a pirate. At Barbados Halley and his men fell sick with a "severe pestilentiall dissease."[5] As one letter from Halley is dated July 8, 1700, at Bermuda and the next is dated August 27, Plymouth, England, it does not appear that he paid any visit to the American Colonies, although he sailed to Plymouth by way of Newfoundland.

Soon after Halley's return from his second voyage, he was appointed to proceed in the same ship, the *Paramour Pink*, "to observe the course of the Tides, in the Channel of England, in every Circumstance thereof; and to take the bearings of the principal head Lands, in order to lay down the Coast truly."[6]

In 1702 he was sent by Queen Anne to Austria in connection with the organization of seaports on the Adriatic. Halley was presented to Emperor Leopold, "who was exceedingly pleas'd with him, presented him with a Fine Diamond

[3] MacPike, *op. cit.*, p. 107.

[4] *Ibid.*, p. 113.

[5] *Ibid.*, p. 114.

[6] The Admiralty's instructions to Captain Halley were dated June 12, 1701.

Ring, and sent a letter by him to the Queen." This business required another trip to Austria on which again Halley met royalty, this time the Electoral Prince, afterwards King George II, and the Queen of Prussia.

After Halley's return to England in October, 1703, he was appointed Savilian professor at Oxford, in which capacity he was connected with his alma mater until 1719. The only external event to be noticed during this time is Halley's election as secretary of the Royal Society in 1713. The connection with Oxford was, however, the most fruitful period of Halley's scientific activity. In 1719 Halley was appointed Astronomer Royal and remained at this post until his death in 1742.

Looking over Halley's contributions to science, one is amazed at his versatility. His published writings include about 100 items,[7] mostly on astronomical subjects but including also papers on mathematics, statistics, physics, geophysics and history. There are also thirty papers[8] never printed but reconstructed from rough drafts. They were read at various times before the Royal Society. These papers are mostly on physics, although here we meet with subjects more unusual for astronomers such as the height and velocity of bullets, diving bells, force of winds, a method enabling a ship to carry its guns in bad weather, and ancient geography. The full extent of Halley's scientific interest, however, is revealed by the extracts from the journal books of the Royal Society referring to Halley.[9] No papers or notes are left on which these exceedingly numerous reports of Halley to the Society were based. We find Halley discoursing about mathematical problems, unusual plants of St. Helena, ancient measures of weight, fossil shells found by him on Harwich Cliff, a new remedy for some disease of the skin, cuttlefish and flounders, microscopic examination of crystals, observations on the explosion of gun-powder, hurricanes, growth of trees, identification of Roman towns in Great Britain, lobsters and crabs, and a multitude of other topics besides, of course, astronomy and physics. These reports cover the years 1687 to 1696, after which date they stop abruptly.[10]

If we recall that Halley knew and used Latin, Greek and Hebrew and that when he needed Arabic for his translation of ancient treatises[11] he learned it, too, we are not surprised at Newton's reference "to the most acute and universally learned Mr. Edmund Halley."[12]

It is to be feared, however, that even in Halley's time the whole realm of human intellectual endeavor was too much for one man. What is gained in breadth is lost in depth. Halley did not possess either the profundity of Newton or the meticulousness of Flamsteed, and therefore most of Halley's discoveries are flashes of genius without the substantial groundwork.

[7] A list is given by MacPike, *op. cit.*, p. 272.

[8] *Ibid.*, p. 135.

[9] *Ibid.*, p. 210.

[10] MacPike evidently considers all these reports as originating from Halley. He quotes with approval the remark of Mr. H. W. Robinson who copied these extracts that one is "astonished at the variety of subjects dealt with . . . which give an entirely broader view of Halley's interests." It is not possible to say which ones were Halley's own papers and which ones he perhaps merely read in his capacity as assistant-secretary of the Society. Practically all notes begin, "Halley read a paper . . . ," but some notes state definitely that Halley himself was the author while others do not. The above enumeration of the subjects refers to the cases in which Halley's authorship is certain. It would be truly remarkable if observations of human anatomy and physiology referred to in some of these notes were also due to Halley! A future biographer of Halley would do well to investigate why these reports cover only nine years.

[11] Apollonii Pergaei de Sectione Rationis Libri Duo ex Arabico MS. Latine versi. . . . Opera & Studio Edmundi Halley, Oxonii, 1706. Menelai Sphaericorum libri III, quos olim, collatis MSS. Hebraeis et Arabicis, typis experimendos curavit. . . . E. Halleius, Oxonii, 1752.

[12] Preface to the first edition of the *Principia*.

Among these discoveries some have proved of great importance in science. Such, for instance, was the secular acceleration of the moon's motion found by him in his study of ancient eclipses.[13] Halley could not prove it, although he was sure of it. Later this effect was shown to be due to the retardation of the axial rotation of the earth owing to oceanic tides. Another discovery of Halley's, that of proper motions of the stars, became of fundamental importance to our knowledge of the sidereal universe. Halley merely noticed[14] that the positions of the stars Arcturus, Aldebaran, and Sirius had changed as compared with their positions in antiquity. The great significance of this discovery apparently escaped Halley who thought that perhaps the obliquity of the ecliptic had changed. His third discovery of potentially great value was the possibility of estimating the age of the world by the amount of salt in the ocean.[15] This method is at best approximate, but even rough calculations would have shown that the ocean must be millions of years old. Whether Halley made the necessary calculations is not known, but he remarks at the end of his article that "perhaps . . . the world may be found much older than many have hitherto imagined." Such reflections might well seem impious in an age when John Lightfoot, Vice-Chancellor of Cambridge University, demonstrated that "heaven and earth, centre and circumference, were created together in the same instant" and that "this work took place and man was created by the Trinity on the twenty-third of October, 4004 B.C., at nine o'clock in the morning."[16]

Halley's contributions to the subject of terrestrial magnetism were of great importance. As a result of his voyages, he constructed magnetic charts indispensable in navigation. His numerous observations of meteors, aurorae, eclipses, etc., must also be mentioned. It is to be noted that he could not discard the ancient idea that meteors were terrestrial exhalations set on fire in the heavens.[17] He definitely linked aurorae[18] with terrestrial magnetism and thought them to be analogous to an electric discharge in accordance with modern views. Describing[19] an eclipse of the sun in 1715, he mentioned and correctly interpreted the phenomenon known now as Baily's beads supposed to have been discovered in 1836.

Halley's most famous discovery was the periodicity of the comet observed by him in 1682.[20] Applying Newton's theory of gravitation to this comet, he showed that its path around the sun was substantially the same as that of the comets observed in 1607 and 1531. On further examination of records, he found that comets were also observed in the years 1456, 1380, and 1305. Accordingly, this comet must have a period of about 76 years and must return to the sun either at the end of 1758 or the beginning of 1759. Halley even allowed for the perturbation of Jupiter which retarded the perihelion passage of the comet in 1759.

The comet, now known as Halley's Comet, was in perihelion in 1759 and again in 1835 and 1910. Its previous apparitions have been traced down to 467 B.C. Comets, the prodigies and omens of the Middle Ages, were shown to obey the law of gravitation, and science could predict their motions. The impact of Halley's successful prediction upon the minds of those who watched the return of his comet in 1759 was great. Halley knew that he could not hope to live to see the comet again and said, "If it

13 *Phil. Trans. Roy. Soc.*, 19, 160, 1695–7.

14 *Phil. Trans. Roy. Soc.*, 30, 736, 1717–19.

15 *Phil. Trans. Roy. Soc.*, 29, 296, 1714–16.

16 A. D. White, "A History of Warfare of Science with Theology," Appleton and Co., 1920, vol. I, p. 249 ff.

17 *Phil. Trans. Roy. Soc.*, 29, 159, 1714–16.

18 *Phil. Trans. Roy. Soc.*, 29, 406, 1714–16.

19 *Phil. Trans. Roy. Soc.*, 29, 245, 1714–16.

20 *Astronomiae Cometicae Synopsis*, Oxon., 1705.

should return, according to our predictions, about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman."

Halley, the universal genius, has left indelible traces in the history of astronomy. His ability to derive correct conclusions from the often inadequate data at his disposal was phenomenal. He was not given to idle speculation as were most of his contemporaries.[21] In fact his analysis[22] of the measurement of stellar diameters by Cassini is a fine example of scientific criticism.

In only one branch of astronomy, astrometric measures, Halley's contributions are not impressive. He had the correct idea as to the method of determining the parallax of the sun by the transits of Mercury and Venus, but his own attempts to observe Mercury on the disk of the sun resulted in a very poor figure for the parallax. However, he drew the attention of astronomers to the importance of the transit of Venus in 1761 and predicted the circumstances of the phenomenon with a good degree of accuracy considering his means of information.

As has been mentioned before, Halley at the age of 20 conceived the idea of forming a catalogue of southern stars invisible from the latitude of central Europe. King Charles II was pleased with the project and gave Halley a letter of recommendation to the East India Company. This company agreed to transport the astronomer to the Isle of St. Helena and to provide him with proper accommodations. Halley's father allowed him £300 per annum for the necessary expenses. Halley spent about two years on this journey (1676–78) of which at least a half year was spent at sea.

Halley's main instruments were a brass sextant with a radius of 5½ feet and fitted with telescopic sights, a quadrant with a radius of about 2 feet, a telescope 24 feet in length, and a good pendulum clock. On arriving at the island he was disappointed to find climatic conditions much worse than he had been led to believe, and consequently he determined the positions of only 341 stars. This work was published in 1679 under the title *Catalogus Stellarum Australium.*

In order to appreciate the importance of this attempt, we must remember that at the end of the seventeenth century there were no catalogues of southern stars. Some observations by Americus Vespucius, Andrew Corsalio, and other navigators were collected by Peter Theodore and were made use of by Bayer in 1603 for his charts of the constellations, and in 1624 James Bartsch published a catalogue of 136 southern stars also based on casual observations by navigators. The necessity, therefore, of a more correct and larger catalogue was obvious both from the viewpoint of science and from practical needs of navigation. The task which Halley set for himself was timely and important and gives credit to the acumen of so young a man.

The results, however, were definitely disappointing both in quantity and quality. The title of "the Columbus of the Southern Sky"[23] must be reserved not for Halley but for Nicolas Louis de Lacaille who, beginning in 1751 at the Cape of Good Hope, within 14 months observed the positions and brightness of no fewer than 9,766 stars. Flamsteed, the first Astronomer Royal, eminently qualified to pronounce judgment on astrometric work, was not of a flattering

[21] To be sure, Halley tried to explain some peculiarities of the earth's surface by the action of comets and was wondering about the primeval light in connection with nebulae, but all this was mild in comparison with vagaries of Whiston (*A New Theory of the Earth*, Cambridge, 1708).

[22] *Phil. Trans. Roy. Soc.*, 31, 1, 1720–21.

[23] B. A. Gould, *Uranometria Argentina, Res. Obs. Nac. Argentina*, 1, 1879.

opinion of Halley's catalogue in spite of his earlier and perhaps ironic reference to Halley as "our southern Tycho." It does not appear that the catalogue was of much use even to the mariners.[24] It was in no sense a fundamental catalogue but merely consisted of differential measures of new stars in reference to stars already observed by Tycho. Halley himself called his catalogue a "*supplementum Catalogi Tychonici.*" This catalogue of southern stars was, however, the foundation of Halley's fame.

I have dwelt at some length on this piece of work by the youthful Halley because it illustrates his inherent weakness as a practical astronomer: his brilliancy of conception and inadequacy of execution. That he was an arduous observer can not be doubted. If we consider the closing years of his career, Halley, as Astronomer Royal, according to his anonymous biographer,[25] observed from 1722 to 1740, "during all which time he has scarcely ever lost a Meridian View of the Moon, either by Day or Night, when the Heavens would permit her to be seen." Yet the desire to observe does not of itself make a good astronomer. Halley evidently lacked the ability to pay sufficient attention to the minutest details which are so important in astronomy of position.[26] Perhaps he was too brilliant for that.

Observations of the moon during the nineteen-year period of the revolution of its nodes were necessary and highly desirable, but the results of Halley's observations were never published. They exist in the form of four notebooks full of extraneous matter and sometimes unintelligible. According to Baily,[27] neither Halley nor anybody else could make the slightest use of them. Often it is impossible to say with which instrument the observations were made or which clock was used. The errors of the quadrant were not determined, and the clocks were very inaccurate. As Baily says, ". . . it will undoubtedly sound strange to the modern astronomer to be informed that one cause of the irregularity of the clocks arose from the bob of the pendulum striking against the sides of the clock case."

The reader should be reminded, however, that Halley was appointed Astronomer Royal in 1720 at an age when in our time most scientific workers begin to think of retirement. The observations in question were made by Halley between the age of sixty-four and eighty-six.

Halley's name will always be connected with one of the greatest works of human genius, "Philosophiae Naturalis Principia Mathematica," by Isaac Newton. In the preface to the first edition[28] Newton pays a handsome tribue to Halley who "not only assisted me in correcting the errors of the press and preparing the geometrical figures, but it was through his solicitations that it came to be published; for when he had obtained of me my demonstrations of the figure of the celestial orbits, he continually pressed me to communicate the same to the Royal Society, who afterwards, by their kind encouragement and entreaties, engaged me to think of publishing them."

The story of the publication of the "Principia" and Halley's rôle in it is

[24] The catalogue was reprinted by F. Baily in *Memoires of the Royal Astronomical Society*, vol. 13, 1843. In his introduction Baily refrains from any criticism of Halley's work, but the mere fact that Halley's catalogue was included among the "ancient catalogues" of Ptolemy, Ulug Begh, Tycho Brahe, and Hevelius is significant.

[25] Probably Martin Folkes, president of the Royal Society, 1741–52. See MacPike, *op. cit.*, p. vi.

[26] De Morgan remarked: "The period during which he held the post of Astronomer Royal, compared with those of his predecessor Flamsteed and his successor Bradley, is hardly entitled, if we look at its effect upon the progress of science, to be called more than a strong twilight night between two bright summer days."—MacPike, *ibid.*

[27] *Mem. Roy. Astr. Soc.*, 8, 169, 1835.

[28] "Sir Isaac Newton's Mathematical Principles," etc., Univ. of California Press, 1934.

well told in a recent biography of Newton by L. T. More[29] which makes use of many documents hitherto unknown. Suffice it to say that Halley not only jarred Newton out of his inactivity but also supervised the printing of the book from the beginning to the end. Even more than that, since the Royal Society was in a poor financial condition, Halley financed the whole publication although he was by no means a wealthy man. He was glad to accept a position as assistant to the secretaries of the Society at a stipend of £50. Even this small sum sometimes was not paid in cash but in the form of unsaleable books published by the Society. Evidently Halley considered it worthwhile to undergo financial embarrassment in order to ensure the publication of the "incomparable treatise."[30] No wonder that Newton, deliberating upon the title of the book, wrote to Halley, ". . . I retain the former title. 'Twill help the sale of the book, which I ought not to diminish now 'tis yours."[31] Fortunately the *Principia* sold well, and Halley does not appear to have sustained any financial loss.

Halley is described by his contemporaries[32] as "of a middle stature, inclining to tallness, of a thin habit of body, and a fair complexion"; ". . . he always spoke as well as acted with an uncommon degree of sprightliness and vivacity." Several portraits of Halley are in existence. The one reproduced in this article represents Halley at the end of his career when he was eighty years old.[33] The influence of Halley on his contemporaries must have been great both by his published researches and in private conversation. He was generally liked and admired with one conspicuous exception. That exception was Flamsteed, Astronomer Royal and predecessor of Halley in that post. The quarrel between Flamsteed on one hand and Halley and Newton on the other constitutes a blot on the memory of these great men. The bitterness shown by Flamsteed toward Halley, who was "not ashamed to borrow where he can, but he blushes whenever he is forced to acknowledge it,"[34] was extraordinary. Flamsteed had "no esteem of a man who has lost his reputation, both for skill, candour, and ingenuity, by silly tricks, ingratitude, and foolish prate: and that I value not all, or any of the same of him and his infidel companions. . . ."[35] The climax of the quarrel was reached when Halley was appointed to act as editor of Flamsteed's "Historia Coelestis," which was published in 1712 at which time most of the edition was burned by its irate author. This book was finally re-published in 1726 after Flamsteed's death.

It would take us too far afield to consider this quarrel in detail. It is sufficient to say that Flamsteed was not the only one to blame. The animosity between Halley and Flamsteed was greatly enhanced by their utterly different personalities. Halley was a brilliant man of the world, accepted by royalty and well known in scientific circles at home and abroad. Flamsteed was a conscientious plodder, shut up in his observatory and in poor health. Being a clergyman, he naturally considered Halley's skepticism of the Bible as atheism. The charge of atheism in so far as Halley is concerned does not come from Flamsteed only, but there is little to substantiate it.

[29] Isaac Newton, Charles Scribner's Sons, N. Y., 1934.

[30] Letter of Halley to Newton of May 22, 1686, More, *op. cit.*, p. 305.

[31] Letter of Newton to Halley of June 20, 1686, More, *op. cit.*, p. 309.

[32] MacPike, *op. cit.*, p. 261.

[33] This portrait is reproduced as a frontispiece in MacPike's book.

[34] Dreyer, Flamsteed's Letters to R. Towneley, *Observatory*, 25, 280, 1922.

[35] Letter of Flamsteed to Newton of February 24, 1691–2, More, *op. cit.*, p. 364. The reader, however, must make allowance for the temper of the times. Flamsteed later was just as bitter toward Newton, and Newton did not mince words about Robert Hooke.

Halley enjoyed robust health almost until the end of his days. For a few years before his death he suffered from partial paralysis, but he continued to observe until the last few months. He died on January 25, 1742, and was buried in the church yard of St. Margaret, Lee, near Greenwich. Halley's grave was restored in 1854, and the original tombstone was removed to Greenwich where it was let in the wall of the Royal Observatory.

The two centuries that have elapsed since Halley's death allow us sufficient perspective to estimate his place in the history of science. He dazzled his contemporaries by his remarkable erudition, yet he was great enough to subordinate his own considerable talent to the transcendent genius of Newton. Halley's contributions to astronomy, geodesy, navigation, meteorology, and terrestrial magnetism did not produce a revolution in science comparable to the publication of the *Principia,* but his contributions were for the most part of first rank. Above all he was the true son of his age when the rapidly accumulating data of new science made an irresistible appeal to men to draw conclusions which could not be verified until many years later. The fact that most of Halley's generalizations were correct in striking contrast with the wild guesses of some of his contemporaries shows the greatness of the man.

AVERAGE PRECIPITATION CONTRASTS IN THE UNITED STATES

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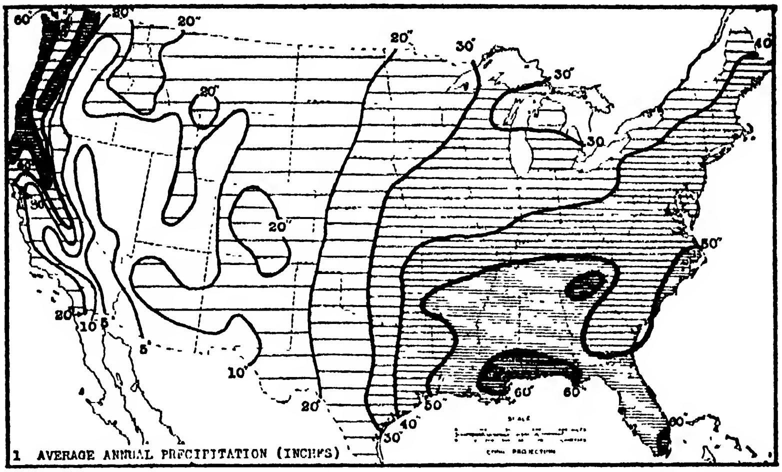
THE range in the United States in average annual precipitation is from 1.5 inches at Greenland Ranch, Death Valley, California, to 128.6 inches at Quinault, near Gray's Harbor, Washington, among the long-established Weather Bureau Stations. A score of other stations with records covering more than 20 years have annual averages of less than 4 inches or over 100 inches. The dry ones are in the Southwest (California, Nevada and Arizona) and the wet ones in western Washington and western Oregon. The greatest average precipitation east of the Coast Ranges is recorded by two stations in the mountains of western North Carolina which have longtime averages of about 83 inches.

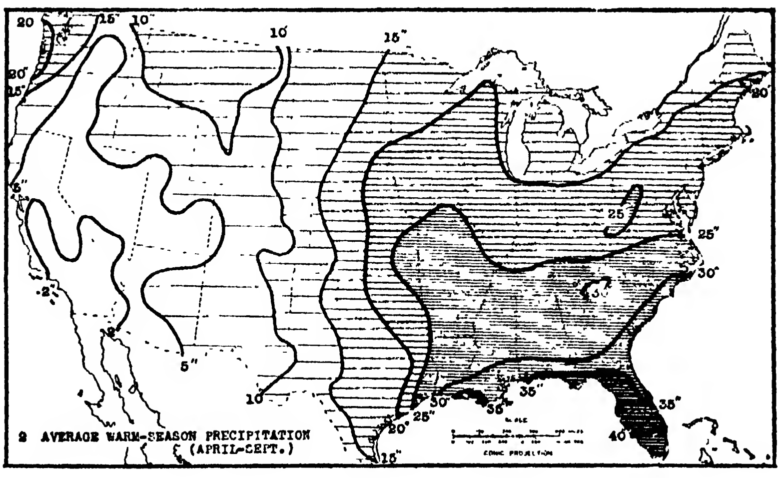
The accompanying Map 1 shows that little of the country receives an annual average of more than 60 inches of precipitation. In nearly one half of the country, less than 20 inches usually is received; nearly a fourth usually receives less than 10 inches a year; in about a sixth, mostly in the Southeast, more than 50 inches is normal. This map, and the others of this article, are shaded redrawings, with some simplification, of maps in the 1941 Yearbook of Agriculture, briefly discussed in the previous article of this series. The Yearbook maps were made under the direction of J. B. Kincer, of the U. S. Weather Bureau. They are based on the data accumulated during 1899–1938 at about 5,000 stations.

Map 2 shows the amount of precipitation received during the normal warmer half-year (April–September inclusive). It indicates that in that half-year, most of the West receives less than 10 inches, about half of it less than 5 inches, and a considerable area less than 2 inches. The largest amounts of rain are received

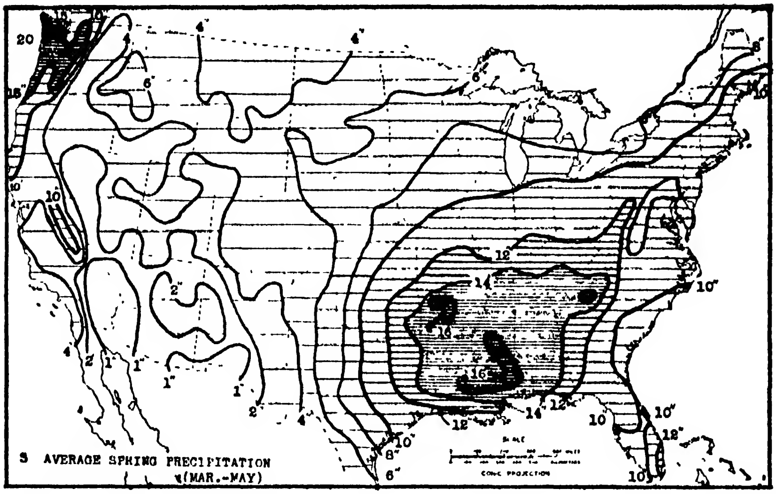


1 AVERAGE ANNUAL PRECIPITATION (INCHES)

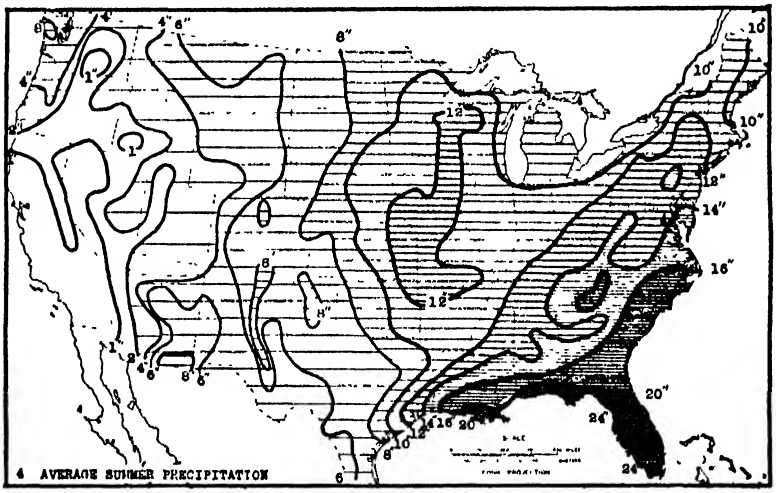
near the eastern margin of the Gulf of Mexico, from which area there is a gradual northward and a sharp westward decline. These decreases partly reflect increased distance from the great source of moisture for most of the eastern half of the United States—the Gulf of Mexico. The moisture is carried northward by "tropical air masses" blowing into eastward-moving cyclonic depressions or Lows which cross the country most frequently north of its middle. The relatively heavy warm-season rainfall of southern Florida is chiefly due to thunderstorms, many of them associated with tropical cyclones of which the most severe are hurricanes. The relative dryness of the West is partly due to the fact that during the warm season, cool winds from off the Pacific become warmed as they blow over the warm land and hence usually are able to retain their moisture. Cyclonic disturbances and thunderstorms, in which the air rises to sufficient heights to induce precipitation, are generally almost lacking in the Pacific Coast states during the warmer half-year. Altitude effects are evident in the southern Appalachians and in the Northwest; just west of the Coast Ranges and Cascades there is relatively heavy rainfall, but just east there is little.



2 AVERAGE WARM-SEASON PRECIPITATION (APRIL-SEPT.)



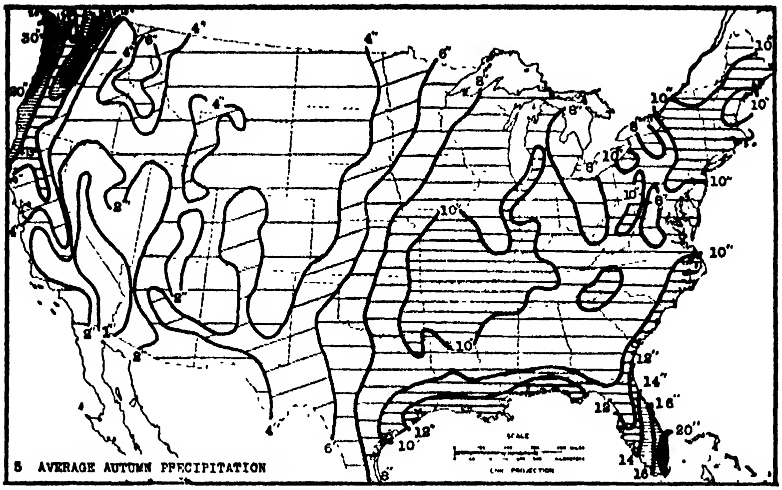
3 AVERAGE SPRING PRECIPITATION (MAR.-MAY)



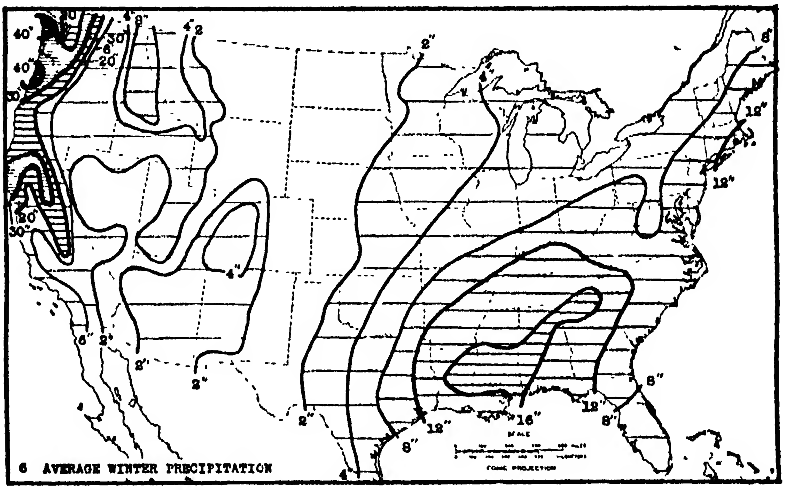
4 AVERAGE SUMMER PRECIPITATION

Maps 3–6 show the average precipitation in each of the four quarters of the year. Spring (Map 3) is a relatively wet season, especially in the lower Mississippi Valley and in the Northwest, where more than 14 inches are received, or an average of more than an inch a week. The driest region is the Southwest. From an area near the mouth of the Mississippi River, this map shows an almost steady decline northward, westward, eastward and even southeastward to southern Florida. Exceptions to this steady decline are caused by the southern Appalachians and the southern Ozarks.

During the summer (Map 4) the heaviest rainfall (16 inches or more) is close to the eastern part of the Gulf of Mexico and in the southern Appalachians. An area of heavier than average precipitation extends, however, from the Ozarks to Wisconsin. California is almost rainless and most of the Northwest receives less rain than the Great Plains. The Great Lakes region receives appreciably less rain than do areas a short distance away. This is due to the fact that in summer the lakes are relatively cool, which coolness interferes with the development of thunderstorms. More-



5 AVERAGE AUTUMN PRECIPITATION

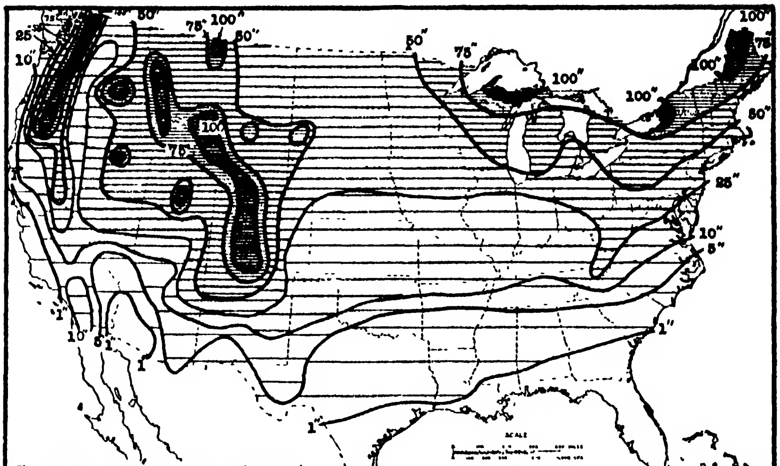


6 AVERAGE WINTER PRECIPITATION

over, winds blowing from the lakes over the warmer land have their capacity for moisture increased thereby.

During the autumn (Map 5) there is a sharp increase in the amount of precipitation near the Pacific Coast but a decline in most of the country. The central area receiving more than average for its region has shifted southeastward from its position in the summer and centers over southeastern Missouri rather than over southern Iowa. A curious northern prong of that relatively rainy area extends to western Michigan, apparently a result of the fact that the winds off Lake Michigan are sometimes sufficiently cooled in autumn by blowing over the adjacent land to cause appreciable local precipitation. The greater rainfall close to the coast of the Gulf of Mexico and the south Atlantic reflects the presence of tropical cyclonic disturbances, most of which yield much more rain on the coast than a short distance inland. Such tropical cyclones are most frequent in late summer or autumn and at that time are common enough, especially in Florida, to affect the average rainfall totals.

During the winter (Map 6) practi-

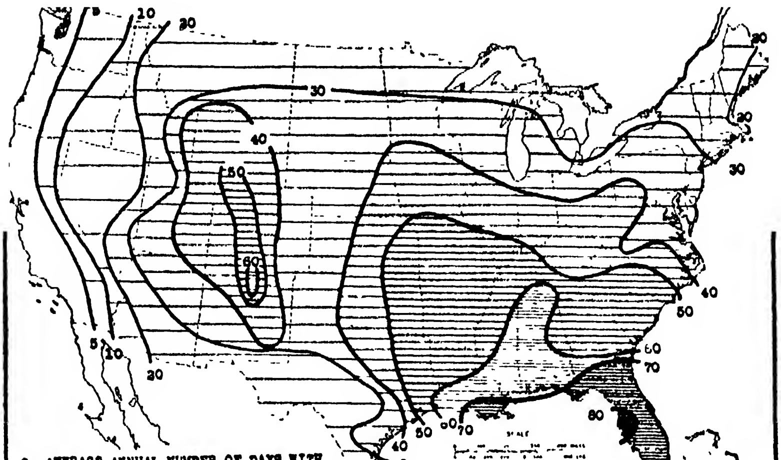


7 AVERAGE ANNUAL SNOWFALL (INCHES)

cally all the country except the Pacific Coast states and part of the Southeast receives less precipitation than during any other season. The central area of more than average precipitation noted in summer and autumn has shifted still farther southeastward, centering in southern Mississippi, somewhat southeast of its position in spring. The general prevalence of westerly winds in winter helps to explain the slight effect of the Atlantic Ocean. A conspicuous feature of this map is the wide west-central belt extending from Mexico to Canada, where less than 2 inches of precipitation is received in winter. The dryness of the winters of that region is a major cause of their grass-cover.

Much of the winter precipitation in the northern part of the country is snow. Map 7, of the average annual depth of snowfall, shows that the average amount of snow increases with latitude, except for Montana, which receives less than Colorado. Along the Gulf Coast less than an inch of snow falls during a normal winter while along the Canadian border several areas receive more than 100 inches (part of which falls in autumn and spring). The influence of the Great Lakes in increasing snowfall to the leeward is indicated. An area just east of Lake Ontario receives 150 inches on the average, more than any other lowland area in the United States. Several western mountain areas receive, however, more than 100 inches, and a part of the Cascades more than 300 inches. The greater snowfall in Colorado than in Montana is partly because more moisture is available, from the Gulf of Mexico, and partly is due to its greater average altitude.

The final map of this series (Map 8) deals with the number of thunderstorms. Such storms are almost synonymous with rain. During the summer they are fairly frequent throughout the entire country except the Pacific Coast, but during the cooler months they are much more common near the Gulf of Mexico than further north. Indeed they are rare or almost lacking in winter in the north. Thunderstorms occur on about a fifth of the days of the year in Florida, some of which days have two such storms. The relatively numerous thunderstorms in the central and southern Rocky Mountains is a conspicuous feature of this map. There they are limited to the summer. A map, not published here, of the annual number of days with damaging hailstorms, shows that hail is much less frequent in Florida than in the western



8 AVERAGE ANNUAL NUMBER OF DAYS WITH THUNDERSTORMS

area with many thunderstorms. In Florida, hailstorms usually damage any area less than once a crop season, in contrast with 4 to 6 times in a large western mountain and High Plains region. Presumably hail is formed in the most violent thunderstorm of the southeast, but at such great altitude that it is usually melted before reaching the ground. In the part of the West where damaging hailstorms are most frequent, the elevation of the ground above sea level averages more than 5,000 feet. A belt some 300 miles wide along the Atlantic and Pacific coasts has fewer than 2 damaging hailstorms a year in each locality. About half of the country, west of the Mississippi River and north of Louisiana, has an average of 3 or more. Hail storms are less frequent along the Canadian border than farther south, just as are thunderstorms.

Calculations by Kincer indicate that the average annual precipitation of the western third of the country, from the Pacific to the Rockies, is 18 inches; the average for the zone from the Rockies to the Mississippi River is 28 inches; the average for the region east of the Mississippi River is 43.5 inches. For the country as a whole (weighted State averages), the normal amount is 29 inches.

The amount of precipitation in any region depends upon two main conditions: the amount of atmospheric moisture, and the frequency and adequacy of the cooling of large volumes of air sufficiently to cause precipitation. The great source of atmospheric moisture is the sea, especially warm bodies of water from which there is much evaporation. For the United States east of the Rockies, the great source of moisture is the Gulf of Mexico. The agency that transports the moisture to the land is, of course, the wind. Most of the surface winds of the United States are cyclonic, and most of the rain-bringing winds spiral into Lows. Sufficient cooling to cause precipitation is accomplished in three chief ways: having the wind blow against mountains (orographic rain) or override cold bodies of air or to rise in thunderstorms. Warm moist air which blows northward into higher latitudes is cooled thereby, especially if it blows over cold land. In the United States, however, southerly winds seldom cause precipitation except where one of the three conditions just mentioned is present.

The distribution of precipitation in the United States shown by Maps 1–7 reflects regional contrasts in the operation of the several agencies or conditions

just mentioned. The general northward decrease in the eastern part of the country is largely due to increased distance from the Gulf of Mexico; the decline from the Pacific eastward to the Great Plains likewise reflects the inability of moisture from the ocean to reach far inland. The decline is especially abrupt because of the nearby mountains, just east of which there is little rain. The effect of mountains in increasing precipitation on their windward slopes is strikingly shown on the western slopes of the Coast Ranges, the Cascades and the Sierra Nevadas, but is also evident in the southern Appalachians and in the Rockies. The influence of thunderstorms as a cause of local convectional cooling is shown by the general correspondence between the frequency of such storms and the annual amount of precipitation. (Compare Maps 1 and 8.) Two departures from this general correspondence are the Pacific Coast, where there is much rain but few thunderstorms, and the southern Rockies, where there are many thunderstorms but not much rain. The scarcity of thunderstorms near the Pacific correlates with the general lack of warm-season rainfall. Many of the thunderstorms of the Rockies are "dry storms" yielding little rain, but often starting forest fires by their lightning.

The seasonal shiftings of the somewhat central region of more than average precipitation is one of the interesting features of Maps 3–6. These shiftings reflect seasonal changes in average temperature. In the summer, the continental interior becomes relatively warm, below-average air pressures develop, and inflowing winds result. These inflowing winds bring moisture, part of which is precipitated in convectional thunderstorms. As most of these thunderstorms develop in eastward-moving cyclonic depressions or Lows, most rain occurs to the southeast of the warmest part of the continent. As the months pass, the continent cools off until in winter its center is quite cold as compared with the ocean. Then it has relatively high average air pressure, and usually out-blowing winds. As a result, the continental interior is relatively dry in winter. Cyclonic disturbances often cross the United States in winter, but the southerly winds they cause are unable to draw much moisture far inland; instead, it is dropped in the South where it is first sharply cooled as it blows northward. The seasonal shifts in the Mississippi Basin area of above-average precipitation therefore clearly reflect the regional contrasts in seasonal temperatures and the differences in air pressure and winds resulting therefrom.

The pronounced regional contrasts in average precipitation depicted by these maps have profound influences upon plants, animals and mankind. The responses are, however, to the actual amounts of precipitation received, not to the average amounts. Hence any discussion of the responses logically follows a description of the subject of the next little article of this series, "Precipitation Variation in the United States."

FOOD HABITS OF PRIMITIVE MAN

II. FOOD—BIOLOGY OR BELIEF

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Taboos Affecting a Variety of Food Items

The taboo against the hen and her eggs somehow became established in large regions of Africa and Asia. Complete prohibition rules over the Wahuma, Wanyamwezi, Ujiji, the Gallas, Somalis and many other tribes. In India too the hen is considered an abomination and its meat tabooed. Mongols also abhor all birds and fish. Elsewhere the prohibition appears in variously modified forms. In Ashanti only girls before puberty may not eat eggs, which they taste for the first time amidst elaborate ceremonies as part of their puberty rites. In Uganda both fowl and eggs as well as mutton are prohibited to women only. The Samoans eat dogs, but despise eggs and chickens. Similarly, the Witoto of Brazil, described as omnivorous, eating as they do rats, mice, frogs, lizards, snakes and turtles, eat the eggs of reptiles but despise those of birds. The Iroquois of New York indulged in eggs of many species of birds, but unlike us consumed them in a state just prior to hatching. The Ashanti who, as we have seen, do not taboo eggs except to girls before puberty, impose the death penalty upon any one who accidentally drops an egg to the ground and breaks it. We have mentioned that one reason given for not eating eggs was their being considered the hen's feces. Other tribes give other reasons such as their having "a weakening effect upon the organs of generation."

Fish, too, did not escape the trap of human fancy and speculation, and the Egyptians were not alone in viewing it as impure. "The Machinga are looked down upon by some other tribes because they eat fish which the Angoni, *e.g.*, never touch," writes A. Werner. Human beings everywhere react with contempt for those who eat a food forbidden to them. Generally speaking, the pastoral peoples of Africa do not eat fish, "nor indeed may they have it in their kraals: all people who drink milk abstain from eating fish and touching it."

The blacklisting of fish as food is far from being limited to Africa, and unlike other prohibitions seems to have originated independently in several continents. The North American Crow Indians of the Plains "practice no agriculture except to cultivate a little tobacco each year for ceremonial purposes. They make little or no use of the fish which abound in the rivers. The women gather wild fruits and berries, collect edible plants and dig wild turnips and other roots. But the people subsist mainly on the products of the chase and lead the life of nomadic hunters." Fish is included under the item of meat so far as the Hindus are concerned and is prohibited to the sacred castes, a classification different from the one accepted by the Catholic Church. We have seen that the Bible, too, prohibited a large number of fish species. Even the Eskimos "never collect shellfish along the shore: they eat them only when they find them in the storage paunch of a slain walrus." Even the Tasmanians, stigmatized as the most primitive or backward human group, had their food taboos, the major one of which was fish. Primitive

they very well might have been, yet they "would rather starve than eat fish," one author reports. In addition, the very act of fishing, like most of man's ways of obtaining an essential food, was subject to specific rules. For example, the agricultural Ganda of Uganda on the shores of Lake Victoria indulge in fishing on a large scale. In this they seek the aid of magic medicines obtained from the priests and offer in return a portion of the catch to the temples, their gods and priests. Moreover, while the traps are set, the fishermen and their families abstain from meat, salt, from relations with their wives and from any acts of courtship.

Generally speaking, meat carries the brunt of the burden of tabooed foods in an almost endless variety of ways. The Eskimo, for example, evolved the most intricate set of taboos serving to segregate all activities centering around sea mammals from those related to the deer. Not only the consumption of their meats but all tools and functions concerning them had to be kept strictly apart. Characteristic of the extension of a taboo is the custom which sprang up in some communities of not permitting a dog to gnaw the bones of a deer when the seal-hunting season was on and *vice versa*. In addition boys and girls before puberty are forbidden the meat of "narwhal, young seals, all small animals, viscera and eggs." The Hottentots proscribe the flesh of all carnivorous animals and the hare to men only. Of course, many sects of Hinduism, Buddhism and some Catholic orders eliminate all meat from the diet of their followers.

On the positive side of the meat ledger we often find a laxity which does not impress us very favorably. Thus most Bantu tribes consider mice and rats a great delicacy, naming it "ndiwo" or relish. Even here prohibition enters. Often, as among the Achikunda, "rats are forbidden to women and to those who offer sacrifice." They are usually eaten roasted. Grasshoppers and worms were widely considered a great delicacy, as were ants and gnats. The truth of the matter is that there are few animals that were not eaten by some group at some time. Often as in the case of the hippopotamus some tribes get their living by eating it while neighboring ones consider that animal sacred. Still others view eating it about as disgusting as we regard eating rats. A rather unique article of diet are body lice, considered a "particular delicacy" by the Witoto of Brazil already referred to, as well as the Hottentots of Africa. The Eskimo also breed an ample stock of lice in their furry dress and with their peculiar cleverness invented a special instrument for gathering them as food. With them eating lice assumes as well a romantic glamor. When a young lady decides to accept a persistent suitor she combs his hair and eats the captured prey. This is a sign to all that her mind is made up and her future husband chosen.

Of special significance are food taboos involving the various sexual stages of women. Many are the cultures that evolved a double dietary standard which imposes special restrictions on women generally, rarely on men. We have already cited several restrictions affecting the period before puberty. Aranda boys, for example, may not eat lizards and pure fat lest they become deformed. Girls, on the other hand, are forbidden to eat echidna, eagle-hawk and brush turkey because these foods are detrimental to the development of breasts. During the period set aside for puberty rites girls, and often boys as well, were subjected to virtual fasting or to prolonged starvation or to special dietary prohibitions which were of course mild by comparison with the physical torture they often had to endure. The widespread nature of these customs which

appear in North and South America, Africa, Australasia and Australia is particularly striking.

Special food taboos for women during their periods of menstruation are equally common. The peak in dietary restrictions is reached, however, in the rules pertaining to the state of pregnancy. These are as ubiquitous as the very phenomenon of dietary regulations. The pregnant Aranda woman denies herself numerous items of food lest it harm the child. The Malayan Semang abstains from large fish, pheasants, monkeys, squirrels or any animal killed with bow and arrow. For some reason the pregnant woman's father often submits to the same taboos. A pregnant Ainu woman may not eat fish or lobster, nor may she do any spinning, while among the Incas of Peru, the husband observed the same dietary restrictions as his pregnant wife. An Iroquois wife abstains from all meat during gestation and eats nothing but fruit and small fish during the last month. These restrictions are encountered all over the earth.

Special prohibitions are also set aside for the nursing mother. These vary from place to place but are strictly adhered to for fear of harming the child. Among the Witoto it reaches a peculiar expression. After delivery, for which process primitive women usually interrupt their daily routine only for a matter of several hours, the Witoto woman presents the baby to the father, who goes to bed with it and observes all dietary rules. These are usually abstentions from meat and with the Witoto involves also not touching his weapon. This custom of the couvade is intended to deceive those who would envy the woman her child, and cast an evil eye.

Mourning ritual more often than not also demands dietary abnegation, as does even mere contact with death. Samoans, like the Incas, must fast four days, after touching a corpse or an object belonging to it. The Dahomeans, on the other hand, fast only three days and abstain from washing. While some tribes, like the Todas of Southern India, merely observe many food taboos on the occasion of death in the family, others like the Eskimos require of all who come in contact with the deceased to remain indoors, avoid all work, keep clothes on night and day, and eat from separate utensils. Mention should also be made of the great destruction of wealth indulged in at death. Not only are wives immolated at their husband's funeral, but large numbers of slaves and vast amounts of property are freely destroyed or buried. The corpse is often loaded with food on his journey into postulated worlds, to feed his rotting body or bribe imaginary guardians along the long road.

Another human element which exerts a mighty influence upon the biological process of feeding is prestige. There is more truth than meets the eye in Lowie's assertion than man is more of a peacock than either an economic or biologic animal. While it is true that man must eat it is also true that he will fast and destroy much precious and hard-earned food, to say nothing of his inflicting inconceivable torture upon himself, when the quest for prestige dictates. "The lack of purely economic points of view is everywhere visible in the life of primitive peoples. On various occasions valuable food-stuffs and stocks of all kinds are destroyed, burned, or thrown away from motives connected with religion or witchcraft," writes R. Thurnwald. The author further adds, "All observation of primitive peoples teaches us that the social motive, the desire for an exceptional position in the group has outweighed the economic motive." The Trobriand Islanders, as observed by Malinowski, afford a relevant illustration. The natives build their yam houses so that their contents can be seen. Extra large yams are framed, painted, deco-

rated, hung outside for display and left to rot. Their owners will seek wild fruits and roots in the forest rather than eat the yams needed for display. In fact the right to display yams at all is a great privilege of the upper class, and poor people must cover the front of their yam houses and fatten on their contents.

A similar example is supplied by the well-known institution of the potlatch. Prestige among the wealthy Kwakiutl Indians is obtained by throwing a party to display one's ability to burn food and blankets, destroy canoes, kill slaves and melt most precious and highly valued decorated pieces of copper. "Furthermore, such is my pride, that I will kill on this fire my copper Dandalayn which is groaning in my house. You all know how much I paid for it. I bought it for four thousand blankets. Now I will break it in order to vanquish my rival. I will make my house a fighting place for you, my tribe. Be happy, chiefs, this is the first time that so great a potlatch has been given." Words like these cause the hearts of all tribesmen to swell with pride. If the invited chiefs who come properly prepared can not match the quantities destroyed by the host they are defeated and lose status.

It should also be mentioned that there are very few cultures which do not indulge in some narcotic, in the form of smoke, bitter or inebriating drink or some drug. Fermenting juices are virtually as old as man and are obtained from whatever staple food happens to prevail. The Aranda chew pituri, the Kirghiz Kazaks of Central Asia drink fermented mare's milk known as kumiss and eat and smoke opium. The Iroquois brew various "teas," chew barks and ferment honey. The Hottentots smoke narcotic herbs, hemp and hashish. The Witoto chew a coca preparation containing cocaine.

The following is typical: The author of the quotation, E. Torday, traveled on a steamer plying Lake Victoria and carrying a load of hemp.

> Hemp smoking is a widely spread and promiscuous practice. In the interests of their health, I intervened, purchased the whole supply and deposited it in the fire. They came to remonstrate and when I tried to explain how bad it was for their health to smoke it they would not believe me; in fact, one man told me that hemp was food, strength and happiness for them and that without it life was not worth living.

We are all familiar with the nineteenth century picture of primitive man who brutelike follows the direct call of his instincts and biological urges. When he hears the call of hunger, he seeks food, just as he presumably indulged in sex relations when his appetite was aroused. Consider, however, how a typical Australian, a savage, by all definitions, fares on his quest for food. "No sooner does a boy begin to go about in the bushes in search of food than he finds himself very considerably restricted as to what he may and may not eat. Should he eat kangaroo tail or wild turkey, or its eggs, then he will become prematurely old; parrot or cocatoo flesh will cause the growth of a hollow on top of his head, and of a hole under his chin; large quail and its eggs cause the beard and whiskers not to grow; any part of the eaglehawk, other than the sinewy legs, will produce lameness, though the strong legs are admirable, as they improve the growth of the same limb; in fact to strengthen the limb, boys are often hit on the calf by the legbone of an eaglehawk, strength passing from the one into the other. Should the podargus, or night jar, be eaten then the boy's mouth will acquire a wide gape." It may well seem that modern man, with all his burden of proprieties and civilized niceties, is no less encumbered in the search of food than his savage Australian brother.

The very manner of eating has also been subjected to a wide range of rules. It is very common for men and women not to eat together. In such cases the

men eat first and apart from the women, and often have separate utensils. Such customs prevail in Asia and Africa, in Greenland, Hawaii, Bolivia and Melanesia. In many cultures it is most compromising to be observed by any one in the act of eating. That our sanitary manners at meals are recent acquisitions or that the fork seems like a vulgar tool to many tribes is, of course, common knowledge.

The Reach of Belief-Tentacles

Just as many foods are often prohibited to girls before puberty and women in their various physiological circumstances, so does the custom prevail in lands where circumcision is practiced to permit certain foods to boys only after that ritual had been performed. Often it is the father or mother or both who are forbidden to taste certain items so long as they have an uncircumcised boy in the family.

Occasionally we encounter sumptuary laws best illustrated by the Inca state which bears great similarities to modern ideals of state socialism. The mass of commoners consisting of agricultural and pastoral workers were obliged to produce a surplus for the maintenance of the upper class of nobles, priests and officials. To secure such a surplus the standard of living of the masses was regulated. They could only wear certain coarse clothes and eat specified simple foods. All choice delicacies, stronger intoxicants and coca were prohibited to them and constituted the exclusive right of the aristocracy.

Equally common in regions far apart are food prohibitions affecting only certain classes, not always those of the lower strata. In India meat-eating is reserved for lower castes only. Often chiefs and rulers are subjected to numerous restrictions while the lay and the slaves are permitted delicious food. In fact, it is the consumption of such food that intensifies the contempt in which they are held. For example, the Tuareg nobles taboo and abhor the flesh of the sheep, camel, fish, birds and eggs, all of which are permitted to the common people. Often the privileged medicine men or nobles reserve for themselves the innards and the organs such as kidney, liver, heart or head, leaving steak and muscle for the others.

Food plays a major role in most religious ceremonies and ritual. It is not only offered as sacrifice to the gods but often specific items are reserved for that purpose and may be eaten only ceremoniously. Eating of the totem would come under this heading. As a rule the animal which was the totem of the group was forbidden food except when it was sacrificed about once a year. Its flesh had to be eaten then by every one so as to renew their symbolic union.

Another force affecting eating habits was the prevalent notion that certain organs were the seats of given virtues and their consumption would therefore inevitably strengthen those qualities in the consumer. Similarly, animals and plants famed for some peculiar characteristic were believed to impart their powers to those who ate them. This belief was a major assumption in primitive medicine. With regard to plants it was expressed as the doctrine of signatures implying that the external appearance of each plant indicated its curative powers and functions. Thus the yellow dandelion was believed to cure jaundice and red petals or blood were used to help anemia. Strangely enough, many good guesses were hit upon by this haphazard method. This erroneous theory also contributed to the expansion of cultivated plants used as herbs. No distinction was made between internal and external application and many herbs found their way into the diet as relishes.

All evidence indicated that cannibalism was not the savages' simple recourse

to the satisfaction of hunger, as early anthropologists assumed. Rather was it a ceremonial function, an expression of jubilation and victory. If the enemy was brave his heart was invariably eaten. Under all circumstances a cannibal feast was not an ordinary meal but usually a strictly controlled ritual affair.

Few primitive societies show any planning for the future. Neither do they show any trend toward private ownership of land, hunting grounds or commercialization of food, though no culture without some form of private property has yet been discovered. The statement "A whole village must be without corn before any individual can be obliged to endure starvation" applies beyond the Iroquois for whom it was meant. With primitive man's strong sense of tribal loyalty food is as social a problem as air, water or hunting grounds. The sale of food to members of one's own tribe is as unthinkable as its sale by a mother to her child and *vice versa.* On the other hand, foresight and economy are often completely lacking. Besides in many cultures the remainder of a meal must be destroyed and those who partake of it may be punished or even killed.

In our own culture the belief prevailed until almost recently that remnants of food formed part of the person who partook of that food. Hence, like hair or nail parings they gave their possessor magical power over that person. It was in fear of such magic that nail parings, cut hair and left-over food were meticulously burnt. Only three hundred years ago these beliefs were accepted in our own culture and the possession of food remnants or nail parings of another person was used as sufficient evidence to condemn thousands during the witchcraft persecution of the Middle Ages. The fact that such men as Francis Bacon and Robert Boyle shared these beliefs should make us pause and think before we ridicule or "explain" the beliefs or, as we prefer it, the superstitions of other cultures.

Conclusions

We may briefly summarize the meaning of the material here presented. To begin with, the simple-minded formulation of man's food problem which for convenience we may designate as mechanistic must be uncompromisingly destroyed. While man does have to eat in order to survive there are numerous factors linked with that process giving it a multitude of expressions.

To understand man one must know not only our provincial society but the expansive horizons of man's variegated past and present. It is then observed that fundamentally man is very much the same to-day as he was many thousand years ago, though the external aspects of his particular institutions and conduct may have undergone large changes. In different cultures, at different times he maintained different assumptions, beliefs, values, institutions and practices. Yet, all the differences we note are fundamentally peripheral in nature.

Man attempted to explain death or thunder and strove to cure disease then as to-day. An expectant mother sought to do well by her growing child then as much as to-day. And primitive man acted on the basis of his aims and assumptions in precisely the same manner as we do to-day except that his aims and assumptions often differed from ours.

The biologically harmful and seemingly irrational food habits of most human cultures must not blind us in our judgment of man. In fact, our very reaction to these habits is in itself an excellent lesson in human nature and conduct. On becoming acquainted with their strange semblance, we immediately designate them as irrational because they differ so much from our own. Since we

consider our own as natural because we have come to regard them as part of the course of nature, we also consider them rational. It then follows that contrary ones must be classified as irrational.

We still lack training in scanning true human perspectives, in overcoming narrowness, emotionalism, and provincialism. In a word, we have not yet mastered a truly scientific approach to man. We fail to see that man is indeed a peculiar animal. He is and always has been capable of great nobility and generosity but also of great selfishness and cruelty. He is capable of great kindness and sacrifice but also of great prejudice and hate. He is a great innovator, a most ingenious discoverer, but can also for centuries persist in harmful habits or beliefs, and even resist with intricate logic any efforts at change. He is both master and slave.

He behaves very much the same in matters of diet which, in the long run, are as much related to biology as any other elements of his culture pattern. Ultimately, all social institutions are closely linked with welfare, satisfaction and survival. And so in matters of food too, man, primitive as well as modern, has displayed amazing courage and ingenuity. Here, too, he gave free rein to his trend to regard the habitual as the natural and to let his customs become part of his culture pattern, his web of belief and practice.

Little need we wonder at the fact that practically all religions came to include dietary notions and regulations. Religion, as A. Eustace Haydon so eloquently stresses, is a way of life. Contrary to the notions of most scientists of the last century, religion is not fear, ignorance or naivete but an integrated summary of the customs, beliefs, values, hopes, explanations and aspirations of each human group. As such, it naturally sanctions those aspects which are accepted and regarded by the group as natural or proper. But it also gives expression to man's quest for a better life, for a world juster than the one that has him in its clutches, for a life in which his innate values of justice, kindness and brotherhood prevail. Since dietary practices, as we have seen, are part and parcel of man's customs, beliefs and rationalizations, part of his institutions as well as his concepts of right and wrong, it was inevitable that they find a niche, often as in India a very spacious and influential one, in his religious lore.

In his quest for food primitive man showed amazing inventiveness and ingenuity, witness the manioc culture of the Witoto, the plantain of Uganda or the agave of Mexico. In the inclement regions of the icy north, in sandy deserts and rocky lands he managed through fantastic adjustments to secure a livelihood and enjoy a fairly well-balanced vitamin diet. With few exceptions his staple food was a vegetable, though, as we have seen, it could also be milk or meat. What is amazing is that in the absence of vitamin knowledge he usually succeeded quite unconsciously to vary his diet sufficiently so as to satisfy all protective requirements. That he is not urged to do so by an inner drive as are many animals is quite clear by the number of cases where he goes wrong. But that he succeeds at all, on an exclusive meat, milk or vegetable diet with often fantastic prohibitions and regulations is indeed a wonder.

As an illustration of an ingenious adjustment manioc may be selected. Its starchy matter is eaten by many South American tribes who originally used it as a source of cyanide poison for their arrows or for the poisoning of lakes or pools during a fish hunt. The fish would become narcotized or would die, rise to the surface and be gathered in with ease. In the course of time it was discovered that what was left over after the extraction of the poison could be converted into an edible bread-like staple. Now,

contrary to the original practice, it is being used as food and its poison is discarded. The plant is ground and washed until all the poisonous compound is dissolved and the residue is used like flour.

Yet primitive man's choice of diet is no more "rational" or scientific in our sense of the word than biological mutations are purposive. Primitive man follows his emotions and reasoning in a thoroughly human manner. What we call magic was his science. Conversely, what many modern, popular writers on food call science is merely the mechanistic magic and superstition of our day, seeking to explain away rather than study fundamental phenomena.

While our knowledge of metabolism, digestion and vitamins has expanded and modified our reasoning on the subject of diet, we have as yet neglected the study of many emotional forces still governing dietary notions. It is a fact that we tend to rationalize our own dietary taboos, such as those against horsemeat, rats or earthworms. The very act of seeing some one eat such tabooed food affects us unpleasantly. It is also a fact that a dietary habit once established is extremely difficult to break. A Hindu friend who had long since abandoned most of his faith took six years to finally eat fish but after ten years' sojourn in London could not muster enough strength to eat beef. Mohammedans who as adults become converts to Christianity or Atheism seldom learn to eat pork or to control their nausea at seeing others eating it.

The kind of food as well as its preparation and eating etiquette tend to become standardized in and characteristic for each culture group, as do all other culture elements. Once established they are modified slowly and with great difficulty. Like language, dress or religion, a diet becomes part of a rational and emotional belief pattern, which in turn exerts a mighty grip on the community. Changes in diet by diffusion or by inner mutation do at all times occur, but they are slow, haphazard, uncontrolled and unpredictable. And the sad fate of the buffalo-hunting Plains Indians who would not and could not become agricultural is a worthy lesson. To weaken consciously the grip of an evil belief and replace it by desirable scientific habits is therefore a stimulating challenge to the social scientist of to-day.

The introduction of scientifically sound food habits into the people of our country requires much study of the type of material here presented and of its varied implications. To know how bad food habits can be displaced and good ones introduced, one has to understand the intricacies of the psychological forces that interplay with the urge to eat. Biology and economics constitute only two variables of this complex equation. Obviously there are more factors and weighty ones at that. People do not develop a taste for oysters on being informed of their excellent dietary worth. Nor do they abandon alcohol, tobacco or a favorite dish on being lectured about their dietary insufficiency. To change bad food habits of a community and put them upon a scientific foundation, more than the biochemistry of nutrition is needed. One must learn to understand custom and cultures and their psychological matrix. One must learn ways and means of loosening old bonds and of introducing new ones.

DOES HISTORY SHOW LONG-TIME TRENDS?

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ARE there long-time trends in culture—broad general movements whose sweep transcends the rise and fall of individual civilizations? The question seems highly pertinent, among other reasons, because of its significance for prediction and control of human affairs. Prediction is based upon the assumption that some patterns of the future bear a discoverable relation to patterns of the past, and intelligent control presupposes an understanding of the manner in which the phenomena operate. If social science is to predict and control—the latter point being one on which not all social scientists agree—the demonstration of cultural trends which have already survived the rise and fall of several civilizations would simplify the problem by providing some probable tendencies around which to orientate predictions and frame controls.

Recent reactions against the social optimism of the eighteenth and nineteenth centuries[1] seem to have reached the point of denying, directly or by implication, the existence of such a thing as social progress or even an orderly succession of generically related events. Ruth Benedict writes:

> Anthropological criticism has been leveled for a long time against the whole assumption that the course of civilization can be made to fit into any rational scheme. The history of the human race is irrational to the point of melodrama. It can be made to conform to "law" only by lopping off everything that will not fit.[2]

Radin maintains that the evolutionary theory of successive stages ". . . has today quite outlived its usefulness and . . . those of its postulates that are still a living force are more harmful than beneficial to ethnology."[3] Goldenweiser claims that

> No anthropologist today believes in an orderly and fixed progression of cultural events. . . . Equally obsolete is the concept of gradual transformation (by "imperceptible gradations"). . . . For no anthropologist believes that any large part of culture is invented, that is, represents the culmination of a process of rational thought.[4] The role of emotional and unconscious factors may not be wholly understood, but all accede that most of what we call culture comes from this source.[5]

Sorokin, firmly convinced that the ". . . progress cult is already out of date . . ."[6] denies at least twenty-one times in his recent work ". . . the existence of a perpetual main linear trend in history and most of the social processes."[7]

1 The eighteenth century social optimism so eloquently stated by Condorcet and Turgot affirmed a profound faith in the inevitability of social progress, asserting that except for temporary reversals, all social change was in an "upward" direction. Spencer popularized "social evolutionism" with its attempt to classify all cultural variations into a series of predetermined categories, which were then assumed to be the successive stages of an evolutionary sequence.

2 Ruth Benedict reviewing Robert H. Lowie's "Are We Civilized?" in *New York Herald Tribune Books*, September 15, 1929, p. 4. (Abridged and quoted by Hornell Hart, "The Technique of Social Progress," Holt, New York, 1931, p. 20.)

3 Paul Radin, "Social Anthropology," McGraw-Hill, New York, 1932, p. 11.

4 Goldenweiser inserts a footnote excepting mechanical invention.

5 Alexander Goldenweiser, *American Journal of Sociology*, 31: 19–38.

6 Pitirim A. Sorokin, "Social and Cultural Dynamics," American Book Company, New York, 1937, Vol. III, p. 535.

7 *Id.*, Vol. I, p. 187. (See "linear trend; lack of" in indices.)

Statements such as these create an impression of culture as growing almost entirely through accidental accretions, fluctuating aimlessly within some possible limits of variability, and showing no long-time trends or rational tendencies. Buried in the footnotes one may find concessions as to the existence of trends in mechanical invention, in the growth of knowledge, and in man's ability to cope with his physical environment. Yet if the comprehensiveness of treatment of a topic bears any relation to its importance, it may be assumed that these conceded trends are not considered very significant aspects of culture. Since the question of just which are the more significant aspects of culture is open to debate, it should be entirely relevant to suggest several apparent long-time trends whose implications may be somewhat more important than much of the anthropological literature would seem to indicate.

1

Possibly the most obvious long-time trend is found in the *increasing breadth and precision of man's knowledge of the* physical universe. The progressive accumulation and integration of facts and the elimination of fallacies has proceeded in practically every field of knowledge (with the exception of a few of the more esoteric branches and specialized arts). Although this process has been neither uniform, steady, nor consistent, each great civilization has forged onward towards new discoveries in at least some of the fields of knowledge, while preserving much of the learning of the past. An example outside the field of industrial arts is that of astronomy: The Egyptians orientated their pyramids to the heavens, and the Babylonians were predicting eclipses as early as 3800 B.C.; the Greek astronomers, Aristyllus and Timocharis, in the third century B.C., constructed the first catalog giving star positions as measured from a reference point in the heavens; Ibn Junis compiled the Hakimite Tables of the planets and was the first to record solar eclipses with scientific accuracy in 977–8 A.D.; Copernicus remade astronomy in the sixteenth century, and the astronomical discoveries of the present "great" civilization are still appearing.

If one traces, as it is passed from one civilization to another, the history of some of the industrial arts, such as glass making[8] or metal working,[9] the story of their development is an even more striking illustration of the successive contributions of diverse cultures. Even though much knowledge has been lost and many arts forgotten, it is obvious that the sum total has been increasing. The mass of knowledge of each civilization consists of its particular contributions plus what it preserves from its heritage. History and anthropology are made possible by the fact that some of the lore and the artifacts of the ancients have survived to form part of present knowledge; otherwise reference to the past would be impossible, and any who would refute the growth of knowledge by comparisons with the wisdom of the ancients overlook the fact that such comparison is possible only because this ancient lore still survives,[10] and is to-day supplemented by modern increments to a total which makes such comparisons futile. The accumulation of millenniums of experience, recouping the losses of successive reversals, now gives man the power to peer a billion light years out into space and see cosmic drama as it transpired a billion years ago,[11] or to

[8] See Frances Rogers and Alice Beard, "5000 Years of Glass," Stokes, New York, 1937.

[9] See T. A. Rickard, "Man and Metals," Whittlesey House, New York, 1932.

[10] For this observation the writer is indebted to a conversation with Dr. Howard E. Jensen.

[11] See *New York Times Magazine*, September 4, 1938, p. 7 plus, for a discussion of the anticipated powers of the 200-inch telescope nearing completion at Palomar.

peer through a microscope and break a pin-point into a thousand fragments; to analyze with a spectroscope the chemical composition of Arcturus, and halt with stroboscope and camera a bullet in its flight. The subdivision of knowledge and investigation into an increasing number of specialized fields is a recognition that the mass of knowledge within a field has become too vast for one man to assimilate, or the possibilities of research too ramified for one man adequately to consider.

2

This first trend has been accompanied by *increasing accuracy and efficiency in recording and diffusing this knowledge of the physical universe.* Since the day when man first began scratching pictographic ideographs on his cave walls some 25,000 or more years ago, he has been refining his methods of recording and diffusing ideas. His development of the phonetic alphabet, probably in the Sinai peninsula, was fairly complete about 4000 years ago, and of Arabic numerals roughly 3000 years later. For about 3000 years libraries have served as growing storehouses for his information. Two thousand years of development of indexes of all sorts—encyclopaedias, gazetteers, concordances, glossaries, dictionaries—dates from the earliest known encyclopaedia, Pliny's thirty-seven volume *Natural History,* written nearly 1900 years ago; to-day, libraries, indexing, and cross-referencing open at a moment's notice the door to records of man's vast experience. The speed and accuracy with which man can preserve and transmit his ideas has been increasing at an accelerating rate as inventors have given him shorthand,[12] lead pencil and fountain pen, durable paper and permanent inks, printing press, typewriter, linotype, teletype, phonograph, radio, dictaphone, photography, motion picture, microphotography,[13] telephoto, television, and important techniques of restoring and preserving manuscripts.[14]

3

Even those who do not believe in trends recognize man's *increasing ability to* MANIPULATE *his physical environment.* An explanation for this trend is found in the accelerating frequency of invention and discovery. Darmstaedter traces the frequency of invention and discovery over 5500 years, with a low point of 22 during the 2700-year period from 3500 to 800 B.C., an increase to 61 during the first century A.D., a decline to four per century during the fifth and sixth centuries, then another quite consistent increase, rapidly accelerating during the latter centuries, to a high point of 2880 for the last quarter of the nineteenth century.[15] It is highly probable that the paucity of ancient invention and discovery and the violence of the fluctuations is somewhat exaggerated by the inadequacy of the records.[16] Even so, a rapid

12 Used at least as early as Greek and Roman times. (See *Encyclopaedia Britannica,* "Shorthand.")

13 See M. H. Savelle, *Library Journal,* 60: 873–8, Nov. 15, 1935; M. L. Randy, "Microphotography for Libraries," American Library Association, Chicago, 1938.

14 See F. Jacobs, *Scientific American,* 155: 260–1, November, 1936; J. Grant, "Books and Documents; Dating, Permanence, and Preservation," Grafton, London, 1937.

15 Pitirim A. Sorokin, *op. cit.,* Vol. II, pp. 134–5.

16 Conclusions concerning early inventions must be based upon the fragmentary evidence offered by the comparatively few ancient manuscripts and artifacts which have survived the centuries, further limited by a "history" which only recently has considered that civil life and technology approach battles and dynasties in historical importance. Common in ancient and medieval times was a cultural ethos in which problems of production were matters for slaves and the poorly-born to wrestle, while philosophy, statesmanship, war, and court life were the proper interests of the gentlemen; thus the educated classes were disposed neither to invent, nor to extoll the inventions of their "inferiors." It is likely that more than one invention was devised, applied, outmoded, and forgotten, leaving no trace for the modern student to discover.

acceleration in the rate of invention and discovery seems an inescapable fact. Indeed it is to be expected from the very nature of the inventive process. Every invention consists in new combinations of old elements, materials, and ideas; therefore, as the number of inventions increases, the possible number of new combinations and applications increases in something like a geometric ratio, and new discoveries usually introduce still further fields of research. It is quite true that many modern inventions are of little consequence as compared with, for example, fire-making or the wheel-and-axle; yet it will hardly be denied that the application of new inventions and discoveries changes living habits and technology far more rapidly to-day than in any previous era.

Further evidence of man's growing ability to cope with his physical environment is found in the trends of production of goods and scales of living. It requires no involved research to conclude that modern levels of production are far higher than ever before, nor does it require a logician to deduce a causative relationship between the trend of invention and discovery and the trend of production. Within recent decades famines have disappeared from that part of the world in which modern methods of agriculture, industry, and transportation have become dominant. For the first time in history, man has it completely within his power to banish famine and pestilence from the earth, a realization which needs await only a peaceful world and a wider diffusion of present knowledge.

A more recent aspect of man's conquest of his environment appears in a flood of synthetic products, alloys, plastics, and new technical processes. Chemists report that instead of being dependent upon a single raw material for a particular product, a growing variety of essential products is now becoming available from several different raw material sources.[17] This is especially true with the coal-tar and petroleum products, most of which can be derived from either source, and the plastics industry, in which almost any basket of vegetables can be turned into radio cabinets and door knobs. The history of technology is showing an expanding variety of material devices, an increasing variety of sources from which a given product or material can be derived, and a growing variety of products or materials through which a given function can be discharged or a given need satisfied.[18] An important effect of this process is to reduce dependence upon any one source, material, or product,—to reduce a society's *vulnerability to economic dislocation* through increasing the technological adaptability; thus the "survival power" of a society is augmented, in so far as problems of economic production are concerned.

4

A fourth long-time trend is found in *the expanding units of cultural interaction,* both cooperative and antagonistic. One aspect of this trend appears in the increasing *size* of political units, from the primitive tribe to the modern empire or commonwealth. With two exceptions (Assyrian and Roman), each "largest" empire in history probably has exceeded all its predecessors in land area,—Early Egyptian, Late Egyptian, Assyrian, Persian, Roman, the Caliphate, the Empire

[17] See William A. Hamor, *Industrial and Engineering Chemistry, News Edition,* 16: 1 plus, January 10, 1938; G. J. Esselen, *Industrial and Engineering Chemistry,* 30: 125–30, February, 1938.

[18] *E.g.,* For lighting, heating and cooking purposes:—To fats, wood, and vegetable fibers have been added coal, natural gas, coal gas, gasoline, kerosene and other petroleum and coal-tar products, alcohol, and electricity. Gasoline and kerosene can be derived from at least two sources, alcohol from at least a hundred, and electricity from chemical action, mechanical power, or combustion of any fuel.

of Ghengis Kahn, and the British Commonwealth of Nations. As the size of political units has expanded, the scope of such activities as warfare has increased similarly. While the *frequency* of wars seems to show neither a consistent increase nor decrease,[19] the *magnitude* of wars has kept pace with the size of the units which wage them, and the *proportion of casualties* has mounted as military devices have become more efficient.[20]

The unit of economic activity has expanded in a similar fashion. Among the primitives, the household, clan, or tribe was an almost completely self-contained and self-sufficient economic unit; to-day the world is an economic unit, with every nation vitally dependent upon economic imports from other nations. The unit of production has shifted through the centuries from the household, clan, or tribe, through the small shop to the large factory or chain of factories; the unit of distribution from the household, clan, or tribe, through the region and empire, until the entire world is now the distributive area for a growing variety of products.[21]

5

A fifth long-time trend, of which contemporary politicians are vociferously aware, is the *expansion of the function of the state.* In addition to such entirely new governmental functions as may appear in a changing world, a great many functions formerly performed by the family or other social groups have gradually been assumed by the state. Anthropologists, studying those peoples whose primitive way of life has survived until modern times and can therefore be studied directly, have found that wherever primitives have lived in very small, isolated groups, such as the Eskimos, Tasmanians, or Semang, nothing resembling a formal government, not even a chief, could be found;[22] among those peoples who lived in larger groups, political organization tended to become more complex, until the governments of the Inca, Aztec, Ganda, and Dahomean nations rivaled their European contemporaries in complexity of structure and function.[23] Anthropologists have found that among the small groups of simpler peoples, redress of wrongs was the function of the individual or kinship group, and order maintained largely through the informal social controls of ridicule and ostracism. Among the larger groups with a more complex material culture such functions as group defense, punishment of crime, and maintenance of order were withdrawn from the individual or kinship group to become the functions of formal governmental authority.[24] It is a logical assumption that this has been an historical process—that the relationship between the size of the group, the complexity of material culture, and the complexity of political organization and function is historically, as well as immediately valid. As the size of human

19 Pitirim A. Sorokin, *op. cit.*, Vol. III, p. 347.

20 *Id.*, p. 337 (see also footnote 28).

21 The recent intensification of economic nationalism and the recurrent discussion of international federation represent two conflicting ideologies, one of which would reverse and the other extend this trend towards larger units of economic activity. It is also possible that scientific development may reverse this trend by making utilization of distant sources of supply less necessary.

22 George P. Murdock, "Our Primitive Contemporaries," Macmillan, New York, 1936, pp. 1–19, 85–106, 192–220.

23 *Id.*, pp. 259–402, 403–50, 508–550.

24 See L. T. Hobhouse, G. C. Wheeler, and M. Ginsberg, "The Material Culture and Social Institutions of the Simpler Peoples," Chapman and Hall's, London, 1930, Ch. II, pp. 46–141. See especially p. 82: ". . . the development of social order is roughly correlated with advance in economic culture. The lowest societies are very small, and even within the smallest groups there is very often no provision for the maintenance of justice. As we advance . . . we get always larger societies, and by degrees provision for the maintenance of justice."

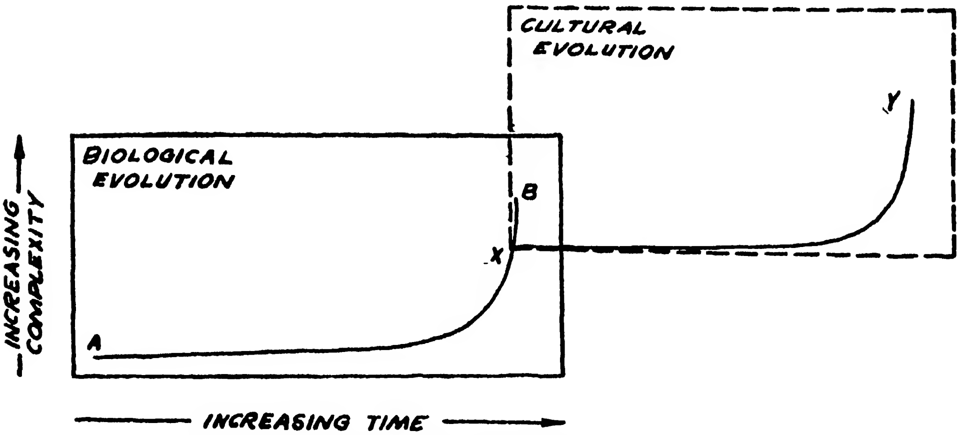
groups has increased, as empires have grown, more and more functions have been assumed by governmental authority —another way of saying that increasingly complex societies have been confronted with an array of constantly more involved problems, for whose collective solution governments have developed. In recent decades this process, like many others, has proceeded at an accelerating tempo, with such functions as education, care of defectives and dependents, and considerable regulation of economic affairs becoming state functions,[25] and indications seem to point towards the continuing functional expansion of the state.

It is quite evident to all careful students that by no means does *all* of human history fit into any series of logically-developing trends, but this admission certainly does not preclude the possibility of there being certain sections of historical phenomena in which trends may appear. In fact, the case for the existence of some trends becomes even more convincing when it is noted that the five trends suggested in this discussion are, to a very considerable extent, mutually dependent and inter-related; *e.g.*, the assumption of more extensive functions by the state is intrinsically related to the growth of scientific knowledge, its preservation and communication, man's control of his physical environment, and the size of the units of cultural interaction.

That there have been violent fluctuations within all of five suggested trends is unquestioned; that they all constitute long-time trends seems inescapable. Possibly the term, "long-time trend," should be defined. "Trend" is defined in Webster's dictionary as an "underlying or prevailing tendency or inclination; general direction taken by something subject to change;" hence even a conservative use of the term would admit that in a diagrammatic representation of a long-time trend, fluctuations of lesser magnitude than the vertical distance between the extremities of the trend line would not invalidate the trend. Now it is quite obvious that all of man's culture —his tools and structures, his technology, his ideas, his habits, ideals and values—have proceeded from crude and simple beginnings to complex forms. This might be termed "the trend of culture," in analogy to the "trend of biological evolution." If biological evolution has proceeded as generally believed by biologists, the course of biological evolution might be represented diagrammatically by a curved line "A–B," with "A" as the beginning of unicellular life, and "B" as the present stage of biological evolutionary development of man. One-celled life, however, possessed no culture; a certain degree of biological evolution is prerequisite to the appearance and transmission of culture. Some degree of intellectual development is necessary before either imitation or tuition of even the simplest adaptations can operate, and at all times the stage of biological evolution sets amorphous upper limits to the possible development of culture. Now, at some point, "X," along the course of biological evolution (without here attempting to determine just were this point should be located), culture must have experienced its penumbral generation. Then, superimposing another diagram with its axes at point "X," the accelerating curve of cultural evolution proceeds to point "Y," the present level of accumulation and complexity of culture.[26] The actual

[25] It should be observed that state regulation of economic affairs is not at all new; in the seventeenth and eighteenth centuries, especially in France under Colbert, such regulation possibly exceeded that at present, yet the *total* functions of the state were certainly far less inclusive.

[26] This diagram should not be interpreted as an attempt to represent "progress" or "improvement," but as an attempt to represent the accumulation and growing complexity of culture. The extent to which these processes may constitute "progress" is a matter for separate consideration.



BIOLOGICAL AND CULTURAL EVOLUTION CURVES

proportions of the curves are not quantitatively determined, nor are the fluctuations indicated; neither is any simple analogy intended. This is rather a diagrammatic representation of the thesis that both biological and cultural evolution have proceeded from simple beginnings to complex forms, and that the present level of culture is more complex than at any earlier period; nor could the curve of cultural development have dropped below point "X," for that point is by definition representative of the simplest possible level of culture. Therefore, despite any fluctuations which would be at all consistent with anthropological evidence, the course described between points X and Y can be nothing other than a long-time trend from simpler to more complex forms.[27]

It can hardly be denied that these several trends constitute important determinants of culture, yet in much of the literature of social science the discussions of long-time trends and their implications are conspicuous by their comparative absence. The modern reaction against "evolutionism" and "progressivism" in demonstrating, for example, that there is no consistent and universal sequence of evolutionary stages from promiscuity to monogamy, from anarchy to democracy, or from a hunting economy through pastoral nomadism to an agricultural economy, has at times tended towards the opposite error of implying that there are not any evolutionary sequences whatever in cultural history. Sorokin avoids discovering any trends among his volumes of statistics by following a simple formula—if there are any *fluctuations,* then there is no trend.[28]

[27] There may be some elements of culture where the tendency has been to move from more complex to less complex forms, as appears probable in the case of religion, for example. Yet such examples do not invalidate the contention that accumulation and growing complexity seem to be far more typical of cultural history than progressive simplification.

[28] In Vol. III, p. 337, of "Social and Cultural Dynamics," Dr. Sorokin presents the following table of data concerning casualty rates in warfare.

PERCENTAGE OF CASUALTIES IN FOUR COUNTRIES FROM THE TWELFTH TO THE TWENTIETH CENTURIES

Century	Casualties as per cent. of army's strength
XII	2.5
XIII	2.9
XIV	4.6
XV	5.7
XVI	5.9
XVII	15.7
XVIII	14.6
XIX	16.3
XX	38.9

Dr. Sorokin then concludes a few pages later that "The study discloses a lack of any con-

In attaching the qualifications, "perpetual linear trend,"[29] "definite, steady, eternal trend,"[30] and objecting that even the trend of population increase (together with all other trends) will be eclipsed by ultimate cosmic chaos,[31] he escapes refutation by defining trends out of existence.

Since the cults of evolutionism and progressivism were closely related to each other in historical emergence and ideological content, it is not surprising that their doctrines of universal sequences of evolutionary stages and of the inevitability of progress should meet joint repudiation. It is not quite apparent, however, just why this repudiation should be extended to preclude the possibility of effective social planning—the calculated pursuit of desired social objectives. Hankins characterizes the position of many social scientists quite correctly in announcing that "The celestially guaranteed progress of the whole society toward idealistic goals *has given place to the concept of mere change.*"[32] It may be no accident that those scholars who pen the most devastating attacks upon trends are often the sharpest critics of the idea that social change can be subjected to any rational direction and control. Hankins maintains that

> Instead of being skilfully directed by social engineers, equipped with clear insight into the social process, the social system will continue to evolve. All we can possibly do is to give it slight impulses here and there, for better or for worse.[33]

DeGrange contends that

> To begin with, there is probably not enough reliable information available concerning "society" to make it possible for an "individual" to be intelligent in regard to it.[34]

Sorokin concludes that

> At the present, all such schemes (for the "*forecast and control* of socio-cultural phenomena") remain as much guesswork and gambling as they were in the past. Only in recklessness perhaps does our present planning abound,[35]

but closes his "Social and Cultural Dynamics" with a dramatic *forecast* of the coming "ideational" era.[36]

One wonders if this frame of mind, when translated into popular parlance, is not related to the almost hysterical anxiety which finds expression in a flood of observations such as these:

> Civilization is not merely on the brink of collapse . . . it has already some years ago collapsed.[37]
>
> In these ten years confidence in the stability, yes, even the basis for existence of human society has largely vanished.[38]
>
> Hope in the Wreck of a Dissolving World.[39]
>
> This life which you lead, a voice says to me continually, is in the deepest sense senseless, a repetition of social gestures, somehow hollow; it ties to nothing, it is a part of nothing. It is a dream, and the reality lies elsewhere. . . . I am in search of a living faith in which to believe, and a body of faith to which to belong. I want to help to create, in order to live in a

tinuous trend . . ." (p. 347). He rejects the usual definition of a trend as *general tendency*, requiring that it be *continuous* in order to qualify. He admits that " . . . all in all, the casualty rates increased faster than the strength of the army . . ." and that "Recent and modern wars have tended to become more devastating in their killing and wounding power" (p. 337), but does not designate these tendencies as trends.

[29] *Id.*, Vol. II, p. 226.

[30] Pitirim A. Sorokin, "Contemporary Sociological Theories," Harpers, New York, 1928, p. 739.

[31] *Id.*

[32] Frank N. Hankins, *American Sociological Review*, 4: 1–15, February, 1939. (Italics mine.)

[33] Frank N. Hankins, *American Sociological Review*, 1: 36, February, 1936.

[34] McQuilken DeGrange, *American Sociological Review*, 4: 118, February, 1939. (Reviewing F. W. Bridgman, *The Intelligent Individual in Society*, Macmillan, New York.)

[35] Pitirim A. Sorokin, *American Sociological Review*, 1: 12–25, February, 1936. (Italics mine.)

[36] *Op. cit.*, Vol. III, pp. 531–9.

[37] Stanley Casson, *Harpers*, 172: 324–31, February, 1936.

[38] Albert Einstein, *New York Times Magazine*, August 20, 1939, p. 2.

[39] Title for a review in *New York Herald Tribune Books*, September 10, 1939, p. 1.

society with which I am intellectually and emotionally reconciled. . . . I am giving publicity to my symptoms only because they are endemic, I believe, to the largest section of western intellectuals.[40]

It is irrelevant to suggest that if the social scientists possess no ability to exercise any rational direction and control over society neither can the less expert laymen hope for any such powers. Accordingly one would have two alternatives; he might hope that society would "continue to evolve" by itself, unconsciously pursuing the ends which we desire, or he could simply resign himself to the impending catastrophe.

In no sense can these attitudes of defeatism and teleological illiteracy be considered as necessary or logical corollaries to the collapse of the cult of inevitable progress. It is conceded that change is not always "upward" and that "progress" has meaning only with reference to some particular set of values or objectives. But why the wide-spread conviction that all human efforts at social planning must be futile and abortive? This ". . . blind alley of defeatism and cynical despair leads only to the inactivity of resignation. Its end product is a neglect of the pressing social problems and tensions of a dynamic society, and the social sciences are reduced to a polite intellectual diversion for the entertainment of the dilettanti."

The question may arise: What implications for prediction and control can be found in the several trends herein outlined? These trends have all transcended the rise and fall of several civilizations with their widely divergent institutions and values. Accordingly, the trends could hardly be simply the accumulations of *accidental* accreations and variations, for it is unlikely that they would *accidentally* accumulate so consistently. Neither is it likely that they can be explained adequately by cultural choices—by selections that are dictated by the attitudes and values dominant within a particular society—for the different societies which these trends have spanned have been quite dissimilar. The explanation of the survival of these trends appears to lie in elements more intrinsic than these factors. Although their survival to date provides no positive guarantee for the future, their antiquity and their accommodation to diverse cultural situations makes the prospects for future continuance something more than a probability. These trends provide some reasonably tenable propositions around which to develop tentative predictions, the indispensable prerequisites to control.

A few examples may clarify this relationship. Consider the well-known trends of population increase, birth rates and death rates. From a study of these trends, predictions as to the future age distribution of the population, the need and demand for old-age relief, the need for teachers and school buildings, the possible expansion of adult education, the probable movement of land values, the expansion of cities and of business areas within cities, the length of life for which public and business buildings should be constructed, and many others may be ventured with greater accuracy. Few chemists share the anxiety of those who anticipate the exhaustion of timber supplies or coal and oil deposits, for the chemist expects that by the time such resources approach exhaustion, the current sources, products, techniques, functions, and uses will have so changed that seldom will any *one* raw material or source of supply be of crucial importance. This increasing technological adaptability seems likely to reduce the economic interdependence of geographic regions, in which case not only will the economic motives for mili-

[40] Dorothy Thompson, *Story Magazine*, 1936; condensed in *The New Current Digest*, January, 1937, p. 9.

tary conquest probably diminish, but the possibilities of self-sufficiency will increase, thereby diminishing the present military advantage of the "have" over the "have-not" nations. If and when physical scientists learn how to add and subtract protons and electrons from atoms at will, then a lump of coal or a glass of water will be potentially anything from hydrogen to uranium and the problem of raw materials will have been solved, for whatever man needs can then be made from whatever materials are convenient. The trend of expanding functions of the state suggests for the future of the democracies a growing concern with the problem of reconciling administrative efficiency with democratic limitations upon authority, perhaps a degree of substitution of vote or job motivation for profit motivation as the basis of the economic order, a further decline of individualistic self-reliance, and a growth of either cooperation or parasitism in society.

These few examples may illustrate how cultural trends that have persisted over long periods in diverse milieu and appear very likely to continue in the future may serve as bases for prediction and control. The existence of a few such tendencies whose continued operation, while not a positive certainty, is an exceedingly strong probability, provides focal points around which further predictions may be orientated. These predictions contribute to the problem of control by defining the areas in which controls may need to be exercised if socially-desired objectives are to be attained. This is not to over-simplify the problem of prediction and control, for social scientists confess that absolute precision in prediction will probably never be realized, nor completely effective controls devised. The purpose of this paper is rather to suggest some long-time trends in human history whose significance may not always be fully appreciated, to show how their recognition can aid in intelligent social planning, and thereby to refute the pessimism and defeatism which asserts that man is incapable of bringing society into greater harmony with socially-desired objectives and values.

SCIENTISTS AND TECHNOLOGISTS IN THE WAR PROGRAM

WHERE do we stand in regard to the various elements which make scientific power effective? These are the ingenuity of our inventors, engineers and chemists; the control of the necessary raw materials; productive capacity; and lastly the ability to use aright the weapons when they have been produced.

It is difficult to exaggerate the importance of the chemist, the engineer and the inventor. The "back room boys," as they have been called, have a part second to none to play.

By land, sea and air the "back room boys" are working all the time to go one better than the Germans. To their researches we owe the great advances made in radio location, by which our anti-aircraft guns and night fighters are enabled to find their targets; to them we owe the antidote to Hitler's "secret weapon," the magnetic mine. All the time we are discovering and developing new weapons and new methods, each of which can be traced back to some one, probably quite unknown to the world, in a laboratory or a drawing office.—*Viscount Halifax, British Ambassador to the United States, in an address at the Founder's Day celebration of the Carnegie Institute of Technology.*

BOOKS ON SCIENCE FOR LAYMEN

NEW PATHS IN GENETICS[1]

THE geneticist must endeavor to become a jack-of-all-trades, according to Professor Haldane in the introduction to this series of lectures given at the University of Gröningen, Holland, in March, 1940. A geneticist must cultivate the keen eye of a morphologist for slight differences, the ability to apply the methods of a biochemist, the fund of knowledge of an anatomist, a physiologist and a pathologist. He must be something of a psychologist to deal with problems of behavior, and his studies of races perforce make of him a political scientist, an anthropologist and a taxonomist. He must understand both the techniques and the economics of agriculture, horticulture and animal breeding, he must be a statistician of ability, and on occasion he even becomes an historian. Not even Professor Haldane can encompass all this. The recital serves only to point out the rich relationships of the field of genetics, and to enlist the attention and interest of workers in these other disciplines, to whom the present lectures are primarily addressed.

The four lectures that follow the introduction are devoted to the relations of genetics and biochemistry, embryology and medicine, respectively, and to the development of formal human genetics. If there is little new to the geneticist in these discussions, Haldane nevertheless manages, as always, to provoke thought by the freshness of his point of view and the distinctive clarity of his expression.

Medical men and biologists in general can not fail to be interested in Haldane's discussion of the genetics of human metabolic aberrations, such as phenylketonuria, a recessive condition associated with idiocy or imbecility, or the lethal skin disease, xeroderma pigmentosum, in which all heterozygotes, although not red-headed, are intensely freckled.

The chemistry of gene-controlled flower pigments affords the most extensive illustration of the interlocking research of geneticist and biochemist. It is very interesting that the action of certain genes on the anthocyanin pigment molecule appears to be direct and simple. The molecule is oxidized, for example, at a particular position. This Haldane regards as comparable to the action of the blood group genes of animals, where each gene produces a specific blood antigen. Haldane is willing to speculate that such apparently direct relations may mean that the antigens or enzymes are the immediate products of the genes concerned. This is perhaps over-optimistic, for the directness and simplicity of the final step in a chemical series is by no means always an indication that the entire series is brief and simple. Yet to a biologist the hope that we may be able to study direct gene action is ever tantalizing.

In discussing the role of genes in development, emphasis is laid on the very complex and numerous consequences of a single gene variation. This emphasis serves to counterbalance the apparent simplicity of the biochemical studies previously examined. Grüneberg's studies of the effects, in rats, arising from a cartilage anomaly, and in mice, of the anemias associated with hair color and pattern, afford examples of the extraordinary variety of consequences that may depend upon a single genetic change. Such studies should attract the medical scientist. As Haldane says, "It is probable that all mice and all men carry genes

[1] *New Paths in Genetics.* J. B. S. Haldane. 206 pp. $2.50. March, 1942. Harper and Brothers.

which, in any existing environment, would cause their death after a sufficient number of years." To abolish the genes that lead to the hardening of our arteries and to other diseases of aging is a task not altogether impossible, but one that will no doubt require some hundreds of centuries.

The analysis of other human maladies is farther along. For example, Mongoloid imbecility, like polydactyly in guinea-pigs, is clearly associated both with the deteriorating prenatal conditions that accompany advancing maternal age, and with genetical factors. In this instance, Haldane clearly points out the common error of making a one-sided interpretation of human data. The "extreme eugenist" will place all his emphasis on the variation in incidence between families, the "extreme environmentalist" will consider only the increase in incidence with advancing maternal age.

Haldane further considers the problem of mental defect. He comes to the conclusion that ordinary hygienic measures might eliminate about 15 per cent. of it, and segregation or sterilization a like proportion, while the prevention of inbreeding would be of slight, although not entirely of negligible effect. Really to get at the root of the problem it will be necessary, he points out, "to find means of detecting irregularly dominant genes in individuals who are not defective, and recessive genes in heterozygotes." Actual examination to determine these types by detection of associated effects is one way to attempt this. Mapping the human chromosomes, as discussed in the final chapter, is another. Meanwhile, we can be occupied for the next century or so in classifying mental defects adequately and in working out their genetic bases.

Especially interesting is the demonstration that from a knowledge of the frequency of a gene in equilibrium in a population, and of its relative fitness, the mutation rate of the gene can be determined approximately. The normal alleles of the sex-linked recessive gene for hemophilia and of the autosomal dominant causing epiloia both appear to be mutating to their abnormal alleles at a rate of about one in 100,000 per generation. Autosomal recessive genes, however, are to a great extent not exposed to selection and so are nowhere near equilibrium in the population. This is particularly true in modern Europe, where the equilibrium has been upset in recent centuries by the decline of inbreeding. Recessive characteristics appear to be rare in western countries today because of this. We may expect, however, that the frequency of the recessive genes will increase, because of their additional protection from selection, and consequently the incidence of the conditions they determine will be slowly augmented in the future, unless we find some means of preventing it.

In short, although some of the new paths in genetics are scarcely discernible trails just at present, yet any reader of this book will readily be convinced that the enhanced physical and social welfare of our human species will depend upon their further exploration.

H. B. Glass

SCIENCE FOR AMERICAN YOUTH[1]

When a boy or girl first awakens to an interest in science he is always highly specialized. It is a particular bug or flower, a fascinating electrical effect or a special chemical reaction which occupies his attention to the exclusion of all else. For a time he can not be interested in any subject but that, even though to

[1] *Science Calls to Youth.* A Guide to Career-Planning in the Sciences. Raymond F. Yates. Illustrated. viii + 205 pp. $2.00. 1941. D. Appleton-Century Company.

an adult others seem very closely related. Gradually through the years and increasing study the interest of the youngster expands, but he usually reaches middle age before he has a broad interest in science as a whole. It is because specialization is thus inherent in the process of learning that even adult scientists have so little concept of the scope and the implications of their field of work.

Raymond F. Yates, now patent editor of *Modern Mechanics and Inventions* and formerly editor of *Television*, in this little book intends to supply an antidote and to widen the vision of youthful scientists with a description of the role of science in molding our world and its promise of a new civilization after the war. He argues eloquently that the age of science is yet to come and that our present travail is a glorious beginning, not a tragic end. He includes also chapters on the type of positions open to scientifically trained men and women and describes quite fully the educational plan at Antioch College and the science clubs for high-school students, that were sponsored by the American Institute of the City of New York at the time this book was written but are now conducted by Science Service.

The book contains many excellent full-page illustrations of the young scientists at work. They do not, in fact, illustrate the text but are in sharp contrast with it by showing boys and girls deep in their extremely specialized hobbies. Indeed, one who knows the work of children may well wonder whether the broad generalities of the text will appeal to them. Certainly every teacher of science should know and ponder the information given and the thoughts of the author. For that objective—and even for the youngsters—one could wish that the style were more mature.

GERALD WENDT

THE TECHNOLOGY OF RESINS[1]

SOME of the natural resins are obtained from living trees, but those used in the greatest quantities are fossilized. Hence the question of supply arises. Dr. Mantell and his colleagues (of the Netherlands Indies Laboratories, Brooklyn, N. Y.) assure us that the New Zealand deposits of Kauri, for example, will supply the demand for well over 100 years. They do not concern themselves, however, with the possibility of a sudden and enforced cutting-off of the supply. When it is considered that most of the natural resins stem from Batavia, Borneo, Macassar, Manila and Singapore, the desirability of even greater encouragement to the synthetic ones becomes apparent.

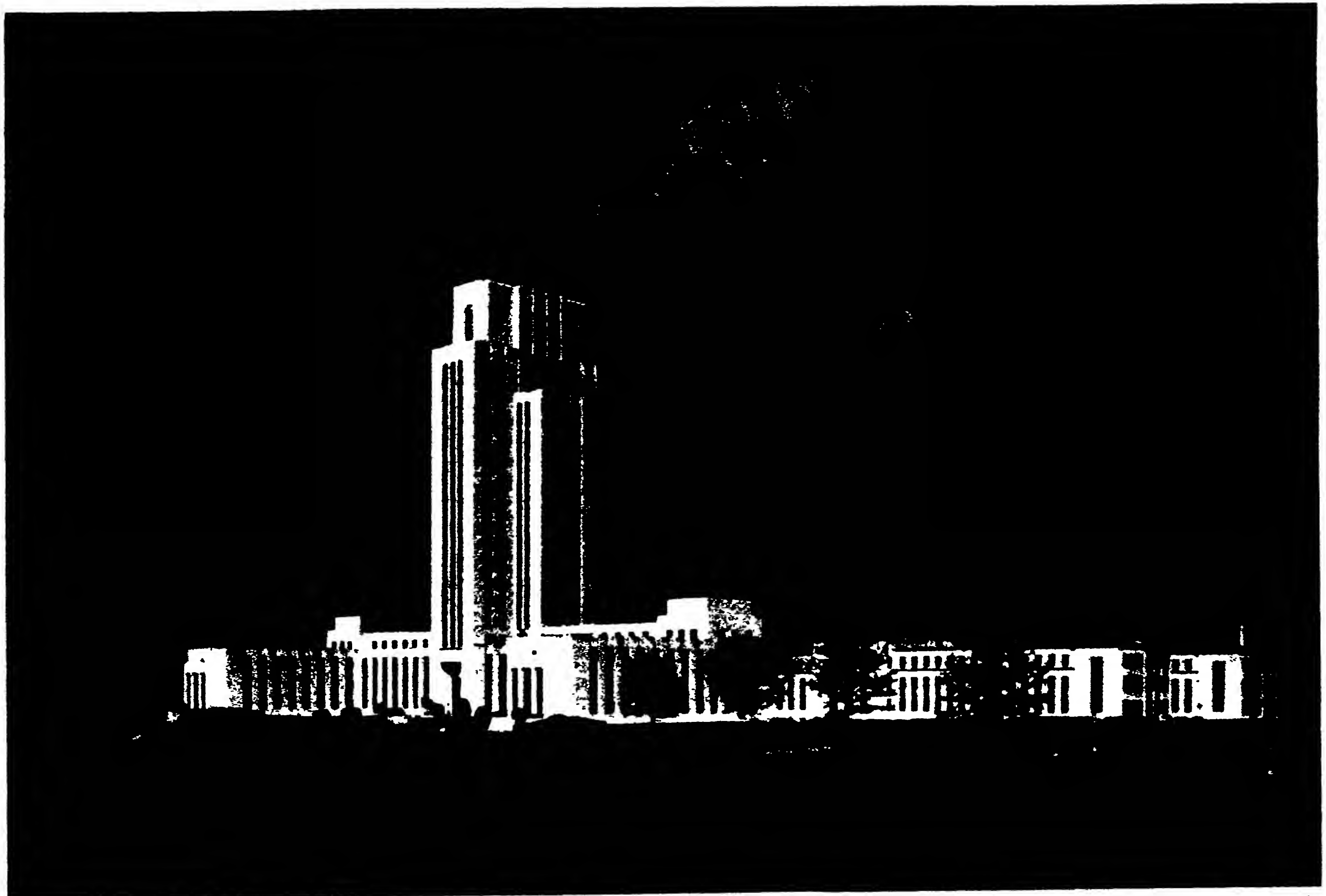
The authors' style is simple, direct, eminently readable. The layman will learn in a very satisfactory way how the following products are dependent upon one or more of the natural resins: Scotch tape, linoleum, printing inks, wrinkle finishes. There is a long discussion of the natural resin content of traffic paint and its influence on durability. Presumably we will have adequate traffic stripes again as soon as we get the rubber to erase them.

However, somewhat more than four fifths of the book is devoted to highly technical details. Numerous formulas for wax emulsions, polishes and varnishes are given, with complete directions for compounding. Table XIX, on the solubility, viscosity and color of natural resins, comprises twenty-four pages; the solvent actions of 131 solvents are dealt with.

Hence it must be reluctantly acknowledged that the book was not intended for the layman, but when one is written, these authors are hereby nominated for the job.

THOMAS B. GRAVE

[1] *The Technology of Natural Resins.* C. L. Mantell, C. W. Kopf, J. L. Curtis and Edna M. Rogers. Illustrated. vii + 506 pp. $7.00. 1942. John Wiley and Sons.



Official U. S. Navy Photograph

NEW NATIONAL NAVAL MEDICAL CENTER NEAR WASHINGTON, D. C.

THE CENTRAL TOWER IS 270 FEET HIGH, ONLY A FEW FEET LESS THAN HALF THE HEIGHT OF THE WASHINGTON MONUMENT.

THE PROGRESS OF SCIENCE

NATIONAL NAVAL MEDICAL CENTER

The National Naval Medical Center was dedicated by the President of the United States on August 31, 1942, in a ceremony that commemorated the one hundredth anniversary of the founding of the Bureau of Medicine and Surgery. The new Medical Center is a fitting tribute to a century of progress in the care of the sick and wounded of the United States Navy. The professional standing of the American naval medical officer has always been an enviable one, and his skill and abilities have accurately mirrored those of the best civilian physicians of his generation. A century ago the American physician was an individualist who treated his patients to the best of his ability, without recourse to specialists or diagnostic centers. The day of specialization had not yet arrived. His contemporary in the Naval Service treated his patients, ashore and afloat, at home and in foreign lands, in the same manner. As medical knowledge increased, it became impossible for the physician to be proficient in all branches of his profession. Men specialized and eventually began grouping themselves into clinics and diagnostic centers, benefiting both their patients and themselves. This trend in the medical world was reflected in the Naval Medical Corps, and qualified officers were given special training in the specialties, and, thereby, the benefits of such specialization were extended to their naval personnel.

The duties and importance of the Medical Corps grew and kept pace with an expanding Navy. Naval hospitals within the United States and in outlying insular bases became clinics and diagnostic centers where naval personnel received medical care that was the equal of the best civilian institutions. The professional and administrative genius that guided and directed the far-flung medical activities of the Navy was the Bureau of Medicine and Surgery. On June 20, 1935, an order authorized the establishment of a Naval Medical Center in Washington, D. C. It was located at 23rd and E Streets, N.W., from the date of its organization until the occupancy of the new site.

The new Medical Center, known as the National Naval Medical Center, is located on a 265-acre tract of gently rolling Maryland land, one mile north of Bethesda and directly across the Rockville Pike from the National Institute of Health. Ground was broken on June 29, 1939, and the corner-stone was laid by President Roosevelt on Armistice Day, 1940.

The buildings are of structural steel, faced with pre-cast, exposed, aggregate-concrete panels. The style is monumental, with a central tower 270 feet in height. The use of dark spandrels, situated between the windows, creates the impression of massive square columns when the building is viewed from a distance. The front of the main building faces west, with the central tower flanked on each side by L-shaped wings, each with four floors. The main corridor extends back from the tower to the auditorium, which has a seating capacity of 600. Secondary corridors extend to the right and left of the main corridor, and communicate with two U-shaped wings with three floors and basement, in each of which are located six general wards.

The administrative offices are located on the first and second floors of the wings flanking the tower and in rooms opening off the main corridor. The operating suite on the second floor directly behind the tower is furnished with the most modern equipment. The main operating room is paneled with pink Tennessee marble and has two glass-enclosed view-

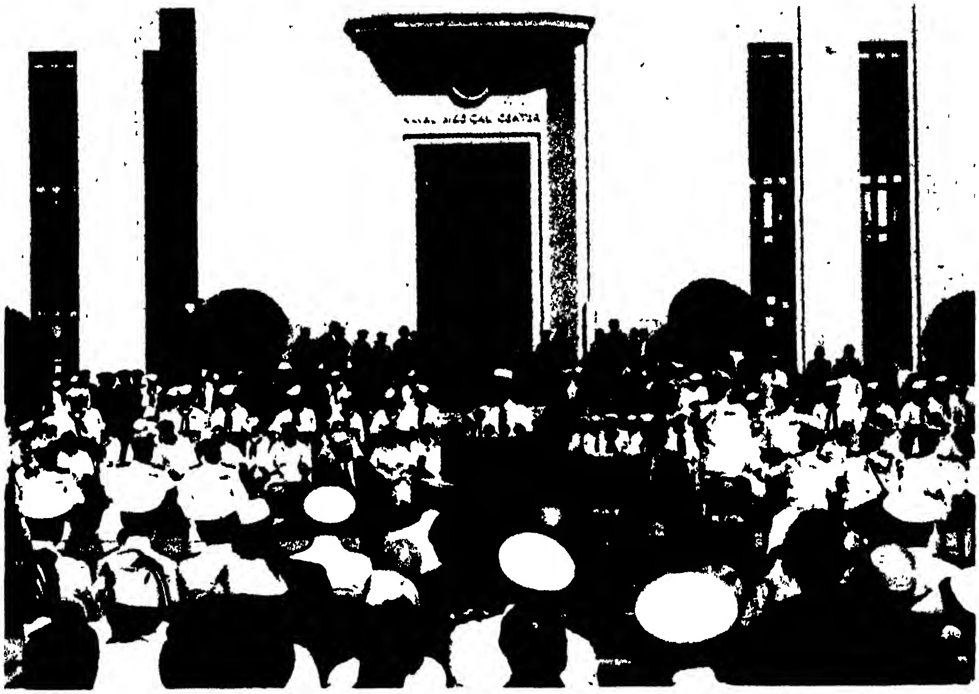
ing galleries equipped with sound devices for the transmission of the surgeon's voice.

The Medical Library contains, at present, more than 40,000 volumes, and has a total capacity of 70,000 volumes. On its shelves are many rare, old volumes dating from the seventeenth and eighteenth centuries. The library is under the supervision of professional librarians. There is a separate fictional library for the use of patients.

The Medical Center is composed of the Naval Hospital, the Naval Medical School, the Naval Dental School and the Naval Medical Research Unit. Each is a distinct administrative unit within the Center. The wards are situated in the U-shaped wings and in the tower. The floor plan of the tower above the fourth floor is that of a Geneva Cross. The fifth, sixth, seventh and eighth floors are general wards. The ninth to sixteenth floors, inclusive, are made up of rooms for one, two and four patients. The seventeenth and eighteenth floors are lounges, solaria and recreation spaces for patients. The x-ray department, on the fourth floor to the right of the tower, is completely equipped with the most modern diagnostic and treatment apparatus.

The Medical School occupies the entire third floor of both wings adjoining the tower. In it are located class and lecture rooms and the various laboratories. The Medical School is used for indoctrination of medical officers who recently have entered the Service and for the training of enlisted personnel in clinical laboratory procedures and in pharmacy and chemistry.

The Dental School occupies two floors of the north wing. It is furnished throughout with the most modern equip-



Official U. S. Navy Photograph

DEDICATION OF THE MEDICAL CENTER BY PRESIDENT ROOSEVELT

THE ONE HUNDREDTH ANNIVERSARY OF THE FOUNDING OF THE BUREAU OF MEDICINE AND SURGERY WAS FITTINGLY COMMEMORATED BY THE DEDICATION OF THE NEW MEDICAL CENTER.

Official U. S. Navy Photograph

A SECTION OF THE MEDICAL LIBRARY

THIS LIBRARY CONTAINS OVER 40,000 VOLUMES, SOME OF WHICH DATE BACK TO THE SEVENTEENTH AND EIGHTEENTH CENTURIES. THERE IS A SEPARATE FICTIONAL LIBRARY FOR PATIENTS.

Official U. S. Navy Photograph

A VIEW OF ONE OF THE MEDICAL WARDS

THE WARDS ARE SITUATED IN THE U-SHAPED WINGS AND IN THE TOWER.

ment. The Dental School is used to indoctrinate newly inducted dental officers, train dental technicians, provide clinical dental treatment for personnel, and carry out studies in dental research.

The research unit will occupy a separate building on the Medical Center reservation. This building will be commissioned and ready for occupancy about November 1, 1942. Here, trained personnel will carry on experimental work in physiology, particularly that dealing with atmospheric hygiene in connection with deep-sea diving and high altitude flying.

The secondary buildings of the center, including living quarters for the nurses and hospital corpsmen, five sets of officers' quarters, power-house, laundry, storerooms and garage, are constructed of materials and a style that harmonize with the main building. Considerable grading of the tract was completed before construction was begun, and landscaping of the site is progressing steadily. When the entire project is completed, the National Naval Medical Center will be a site of beauty and a lasting memorial to those who have planned and carried out its establishment.[1]

FREDERICK C. GREAVES, *Commander*
MEDICAL CORPS, U. S. NAVY

[1] Opinions or assertions contained herein are the writer's and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

NEW RCA LABORATORIES AT PRINCETON

DEDICATION of the new RCA Laboratories at Princeton, N. J., on September 27 marked another step forward in the progress of scientific research and development.

The first laboratory of the Radio Corporation of America was located in a tent at Riverhead, Long Island. That was in 1919. From that small beginning its research facilities and staffs have undergone a process of evolution. They were developed as necessary adjuncts to the several different branches of its business —world-wide and marine radio communication, domestic and international broadcasting and radio manufacturing. Consequently, its laboratories have in general been located at or near its various communication centers, factories and offices where such activities have been conducted. Some of the laboratories have occupied space in plants designed primarily for manufacturing rather than for research and experimentation.

There were two main reasons for the erection of the new laboratories: First, to provide increased facilities specially designed for scientific research and original development work. Second, to make possible the centralization of closely related research activities and their staffs. Demands created by the outbreak of the war increased the desirablity of the move and expedited the plans and construction, as indicated by the fact that ground was broken for the laboratories on August 8, 1941, and the cornerstone was laid on November 15, 1941, three weeks before Pearl Harbor.

The nature of the work required a site large enough to provide effective insulation for the main laboratories from electrical and mechanical disturbances, as well as to provide adequate space for conducting outside radio tests, for the erection of outlying buildings and other structures, and for future expansion. Accordingly a site comprising about 260 acres of farm land was acquired on the edge of Princeton because of its accessibility by the main line of the Pennsylvania Railroad from the principal offices and plants of the company in New York, Camden, Harrison, Indianapolis and Lancaster. It is also adjacent to excellent residential localities from which it can be reached by good roads.

Also, not the least of the attractions

of this area is its inspiring atmosphere, which is so conducive to creative and original work. The state and community are rich in history. The site itself is part of a tract acquired in 1693 by William Penn and is adjacent to a small settlement named "Penn's Neck." Many of the neighbors are institutions and organizations devoted to education, culture, science and research. They include Princeton University, the Institute for Advanced Study, Rockefeller Institute for Medical Research and Walker Gordon Laboratories. The large tract and the necessity for the placing of the laboratories well within it—away from highways and railroads—provide a setting that lends itself to landscaping which will add greatly to the attractiveness of the laboratories.

The design of the buildings is essentially functional. The objective was to attain harmonious utility, simplicity and dignity in architecture. The main practical requirements were for a structure which would provide scientists and engineers with every facility for research and experimental work and for a fully equipped shop in which to make models of experimental apparatus.

The present buildings comprise a main laboratory wing 488 feet long, an intermediate laboratory wing extending 108 feet rearwardly from the center of the main wing, and a shop building, 152 by 182 feet, at the rear of the intermediate laboratory wing.

The laboratory wings are three stories in height with basements. In effect, these wings are built around the electrical, water, gas, air, drain, ventilating and other services required for the conduct of a wide range of electrical, physical and chemical research work. The mains for these services are suspended from the basement ceilings and run lengthwise and centrally of the laboratory wings directly beneath the central corridors on the floors above. The basement also contains transformers, motor generator sets, regulators and air-conditioning apparatus. Thus, the basement is the nerve-center of the laboratories.

Around each steel column on both sides of the corridors in the main laboratory wing are vertical ducts—104 of them—extending from the basement to a penthouse on the roof. Branches are tapped off the mains in the basement and are carried upward through the ducts to the rooms in the laboratories where services are required. The ducts have transite panel sides which are readily removable on all floors to provide complete accessi-

BUILDING OF THE NEW RCA LABORATORIES AT PRINCETON, N. J.

ONE OF THE SPACIOUS LABORATORY ROOMS

EACH LABORATORY HAS BROAD DAYLIGHT EXPOSURE SUPPLEMENTED BY MODERN INDIRECT LIGHTING, WHICH CASTS NO SHADOWS. NOTE THE DUCTS, WITH REMOVABLE PANELS ALONG THE WALL, THROUGH WHICH ELECTRICITY AND OTHER SERVICES ARE FED TO THE WORK BENCHES. FROM THE ELECTRIC OUTLETS ATOP THE BENCHES, ALMOST ANY PHASE OF ELECTRIC CURRENT AT VARIOUS VOLTAGES IS AT THE FINGERTIPS OF THE RESEARCH WORKER.

bility to the enclosed vertical branches from the service mains.

Horizontal extensions are carried from these branches to 420 specially designed laboratory benches each 6 feet long. The electrical services are enclosed in a wiring trough that extends along the tops of the benches and that has panel outlets each of which is marked to show the character of current available from it; *i.e.*, whether AC or DC, its frequency voltage, etc. There are taps on the benches for gas, water and compressed air, as well as for hydrogen and oxygen where they are needed. The drains from the laboratory benches are also run down the vertical ducts, and the ventilating flues from the benches and hoods are carried upward through the ducts to the penthouse where individual blowers exhaust them to the outside.

These distinctive features provide great flexibility for arranging and rearranging the laboratories at any time for any desired class of work or use without disturbing floors or walls.

Some of the outstanding features of the main laboratory wing are a modern two-story television studio, a three-story free field sound room the walls of which are lined with heavy baffles or curtains of ozite so that no extraneous sounds of any kind are heard, a dust-free air-conditioned chemical laboratory especially designed for the study of fluorescent materials, an air-conditioned electron microscope laboratory and a unique optical laboratory. Other laboratories are provided for research pertaining to centimeter wave transmission and reception, receiving, transmitting and cathode-ray tubes, radio facsimile, acoustics and to other subjects associated with the future of radio and electronics.

The intermediate wing of the laboratories will be used temporarily for of-

fices, and therefore has not yet been equipped with vertical ducts and a penthouse. However, removable floor and roof slabs have been provided around each of the columns along the sides of the corridors, so that this wing can be readily converted to laboratory use at any time.

The shop building is a conventional one-story factory type of structure without basement. The model shop in the rear portion of this building is fully equipped with the most modern machinery so that every kind of operation can be performed in the making of models. This building also contains a drafting room, a meter calibrating and storage room, photographic and blue print rooms, a fireproof vault and a kitchen and cafeteria. Temporarily it also houses the library and conference rooms which it is planned to move into buildings to be erected in the future.

In addition to the main buildings the project includes a boiler house, a remote radio laboratory, a spring-fed pool and an adjacent laboratory for under-water sound work, a water supply system including two artesian wells having a combined capacity of 600 gallons per minute, a system of storm and septic sewers, and entrance and other roads. Electrical, gas and telephone services are furnished by the local utilities and are installed underground. Virgin farm land has thus been converted into a complete settlement capable of extensive further development.

THE MODEL SHOP OF THE RCA LABORATORIES

ITS OPERATIONS RANGE FROM GIANT PUNCH PRESSES TO GAUGES ACCURATE TO 5 MILLIONTHS OF AN INCH. MILLING MACHINES, DRILLS AND LATHES ARE LOCATED CONVENIENTLY TO THE WORK BENCHES.

Plans have been prepared for the future erection of additional laboratory wings as required and for an office building for administrative, patent and related staffs. The office building will be located in front of the present main laboratory wing and will contain the front entrance and lobby which will be reached by a diagonal drive from the New York to Philadelphia highway.

These laboratories are not intended as an effort to pre-empt the field of radio and electronic research. In science, as in everything else, competition is the greatest spur to healthful activity. In the alliance of science with modern industry both individual inventors and organized research groups are needed. Each has its field. The flame of some men's genius burns brightest alone. Many of the greatest inventions have been made by individual scientists, with primitive equipment and with little or no help, save the inspiration of their own unquenchable spirits.

But there are many inventions that could never be made and developed in that way. They call for systematic research, and for organizations of men, of materials, of equipment, of resources. The workers in these modern and efficient laboratories will have at their command all these essential factors. They will also have a valuable association with the communications, broadcasting and manufacturing services of the Radio Corporation of America. These services will be sources of ideas for development as well as of problems for solution. They will also be proving grounds for testing inventions and new devices in actual service and production. And the inventions that crystallize here will also be available under licenses to the whole radio and electronic industry.

When the war ends these laboratories will stand dedicated in advance to serve the cause of a victorious peace. For therein lies the distinctive characteristic of scientific endeavor. Its destructive power is one of the greatest weapons of war, and its constructive power is one of the greatest assets of peace. The same radio and electronic discoveries which these and other laboratories will have forged into weapons to tear down the ramparts of our enemies will also serve to rebuild the structures of our peace.

Because men work to-day in laboratories like these, new cities will rise from the ruins of the silent battlefields, richer crops will be harvested from the black stubble of scorched earth, and finer homes—richer at least in material things—will replace the homes that have been devastated by war.

The triumphs of science warrant our saying—amid all the horrors of war—there is still hope for civilization.

To help make that hope come true is the purpose to which these new laboratories have been dedicated.

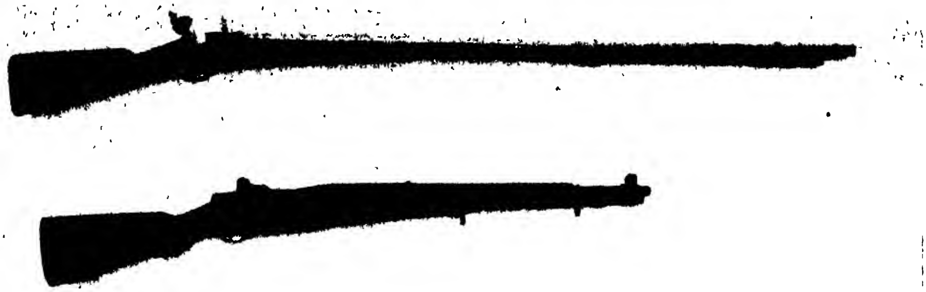
Otto S. Schairer, Director

FIREARMS EXHIBIT AT THE U. S. NATIONAL MUSEUM

The firearms section of the special exhibition now on display in the U. S. National Museum, which because of limited space includes only a small part of the National Collections, is intended to show the major changes that have taken place in firearms during the last three centuries.

The collection includes a number of original patent models, most of which were not practical, but many of which were decidedly ingenious. Matchlock, wheellock and miquelet lock pieces are shown—among the latter two very ornate pieces presented by the Sultan of Morocco to Thomas Jefferson.

For comparative purposes a model of the 1800 U. S. Military musket is shown beside a Garand Ml rifle, the present weapon of our fighting forces. A double-barrel flintlock fowling piece was formerly owned by General Wade Hampton,



FIREARMS OF THE PAST AND PRESENT AMERICAN FORCES
Upper: U. S. MILITARY MUSKET OF 1800. *Lower:* GARAND M1 RIFLE, THE PRESENT WEAPON OF OUR FIGHTING FORCES IN WORLD WAR II.

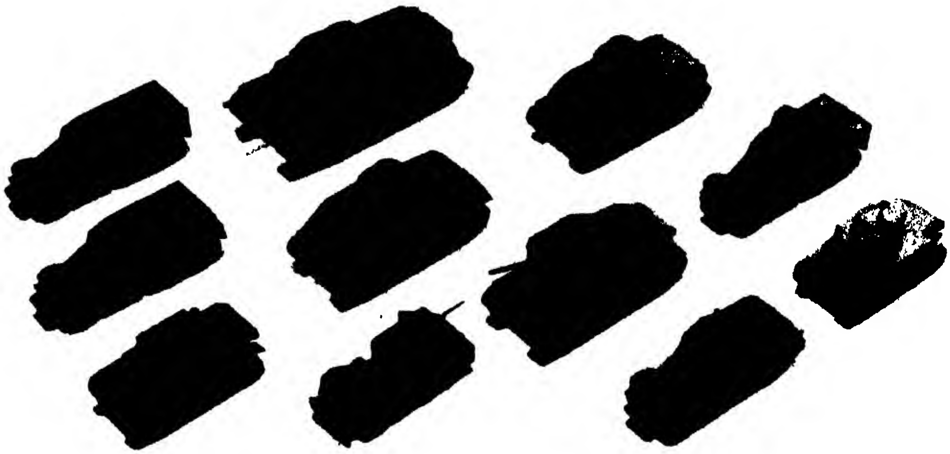
who served in the American Revolution and the War of 1812. With this piece is shown an auto-loading shotgun of the present day.

In the display will be found specimens of the "Brown Bess," the official musket of the British Army in the war of the Revolution, and the "Charleville," a musket of the type brought over from France by Lafayette and presented by him to the American Colonies. This Charleville musket was considered in its day the highest type military arm in the world and was the model from which our first United States muskets were made.

The model 1800 rifle was the first rifle made in United States armories for the equipment of "a rifle regiment," authorized by an Act of Congress in 1799. The "Hall" breechloading musket with its various modifications, the first breechloader adopted by the U. S. Army, was invented by John H. Hall in 1811.

Among the multi-shot pieces are the Porter, a rifle with a cylinder of nine radial chambers which are successively aligned with the bore by a movement of the trigger-guard; the Colt revolving cylinder similar to the Colt revolver; and the "Lindsey," a percussion musket which fired two superposed charges loaded one on top of the other. In this last piece the bullet of the rear charge was intended to act as a gas check and

OLD FOWLING GUN AND MODERN SHOTGUN
Upper: DOUBLE-BARRELED FLINTLOCK FOWLING PIECE OWNED BY GENERAL WADE HAMPTON, WHO SERVED IN THE REVOLUTION AND THE WAR OF 1812. *Lower:* AUTO-LOADING SHOTGUN OF TO-DAY.

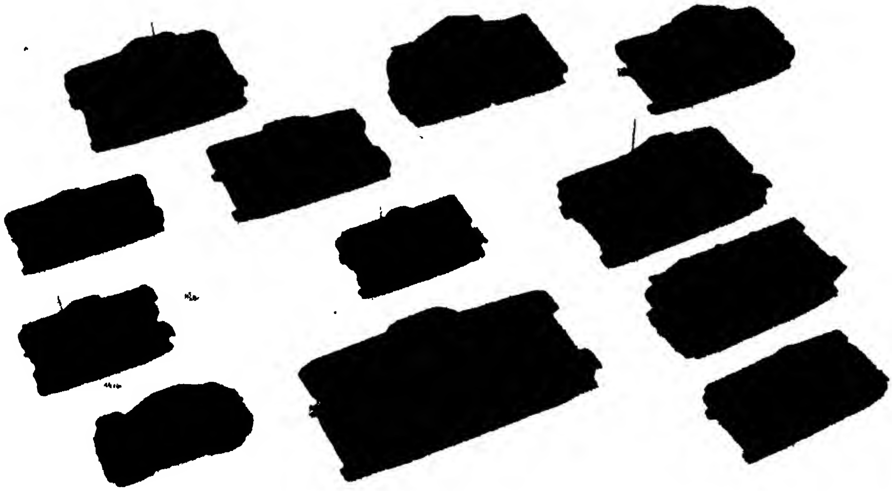


MODELS OF AMERICAN TANKS OF THE PRESENT DAY

breech for the front charge. A repeating pill-lock rifle formerly owned by General Sam Houston, president of the Republic of Texas, is shown. The magazine of this piece is a rectangular block with five chambers which moves horizontally across the breech of the barrel, actuated by the movement of the trigger.

Several cases of modern sporting arms are shown, as well as military rifles, machine rifles and machine guns, and also the shoulder arms of Allied and enemy countries in World War I. The machine guns and rifles include Colts, Vickers, Brownings, the Lewis, Hotchkiss, Mondragon, St. Ettienne, and others.

Pistols and revolvers are shown, dating from the earliest hand cannon, the pistol of the American Revolution, early Colts, pepper-boxes, and others, including the automatic pistols of the present day. One very ingenious piece shown is



MODELS OF GERMAN TANKS USED IN THE PRESENT WAR

the "Mortimer," a flintlock pistol which by a movement of a lever placed a ball in the barrel, filled the chamber with powder and charged the pan with priming. For each movement of the lever a shot could be fired.

Handsome scale models of the 14-inch naval guns used by the navy ashore in France, a model of the 7-inch field gun used by the Marines in France in World War I, and twelve scale models of German Army tanks, and sixteen scale models of American tanks and armored vehicles being used in the present war are included in the exhibit.

CHARLES CAREY

WALTER LOWDERMILK CALLED AGAIN TO CHINA

IN the summer of 1941, before Pearl Harbor, the United States Government received an urgent request from China. Japan had forced some 65 million Chinese from the smoother lowlands of the coastal country back into the rough lands of the interior. Food for the armies and people of Chiang Kai-shek had to be produced on steeper and steeper slopes. Under cultivation the soil was washing from beneath the warring nation. Erosion was sapping the life blood of continued national resistance. The Chinese Government wanted Walter Lowdermilk to come to China and lead the fight against erosion—a foe as relentless and as deadly as the Japanese.

Before Lowdermilk could complete plans for departure he was stricken by a desperate illness. After months in the hospital he was released with the warning that strenuous exertion of any kind would probably have disastrous results. Lowdermilk, however, had fought for civilization in World War I. He had later spent many months in China helping to stave off the frightful effects of famine. So long as there was a spark of energy left in his body he would continue to work for the betterment of mankind, completely oblivious to his own personal interests or welfare.

It was under these conditions that Walter Lowdermilk left for the Orient early in September of this year, accompanied by Dr. Theodore P. Dykstra, of the Bureau of Plant Industry, a specialist in corn and potato breeding.

During his previous stay in China he had learned what it means to a nation to strip its land bare of forest and expose the good earth to the ravages of erosion. It was more than a call to duty that prompted him to undertake the perilous journey, much of it over submarine-infested waters and through skies in which enemy aircraft lurk constantly. He left with the conviction that he could help save a great civilization.

Before his illness, Lowdermilk had nearly completed a survey of that ancient part of the world along the shores of the Mediterranean across north Africa to Syria—through desert, desert-border and lands laid waste by erosion—when World War II struck. He went at the urgent request of former Secretary of Agriculture Henry A. Wallace and myself to see what had happened to the agricultural lands in that part of the old world as the result of man's use of the land across the ages. He returned with heart-rending revelations and a wealth of information showing how civilizations have vanished from this earth as the result of raids, wars and exploitive use of the land. He found the remains of cities, the very names of which are lost to man in the debris of eroded soil—soil that made it possible to build the cities.

Lowdermilk returned to the United States resolved anew to help his fellowmen, regardless of race or creed, to avoid the loss of their productive lands. Never in all my forty years of public service have I known a man—private citizen or public servant—more completely determined to put the interests of humanity

ahead of his own personal desires and well-being.

The request from the Chinese Government called first for a specialist to direct the manufacture of insecticide and fungicide, a specialist to operate a laboratory for the manufacture of livestock serums and vaccines, and a plant breeder for corn and potatoes. Subsequent requests have been made for a teacher of animal husbandry, an animal breeder and a hydraulic engineer. The country is being searched for right men to fill these assignments.

HUGH H. BENNETT, *Chief*
SOIL CONSERVATION SERVICE

ERSATZ IN 1942

STEADILY during the years from 1914 to 1919 the word *Ersatz* came to be associated more and more with crude vegetable fiber and even the bark of trees as substitutes for digestible human food, and with paper and paper products as substitutes for cotton, silk and wool in clothing; it called up specters of hunger, malnutrition, starvation, cold, misery and death.

In 1942 the English equivalent "substitute" has suddenly acquired entirely different connotations. Instead of implying the inferiority of that to which it is applied, it generally carries the promise of inexhaustible new sources of substitutes that are often better than the original materials. Instead of suggesting suffering, it promises comforts.

No sudden shortage of material has affected the general public more acutely than that of rubber. The recent scarcity of rubber has forced the development of substitutes made from various abundant available materials that even at this early period are superior to the natural product in some important respects. A new era in the equivalents of rubber appears to be opening.

One of the essential materials for modern life, in peace and war alike, is steel. The various kinds of steel are not pure iron but alloys of iron with copper, nickel, chromium, cobalt, manganese, vanadium and other elements, in various combinations. The shortage of steel-producing capacity to meet the enormous demands of war and the lack of adequate domestic supplies of certain alloying materials, such as nickel, has stimulated the development and use of "low alloy" steels for structural purposes that will result in enormous advantages. For example, in the production of the 270,000 freight cars that are now needed there will be a saving of a million tons of finished steel, four million tons of raw materials for its making, and enormous amounts in rail and water transportation. There are, however, indispensable alloys using imported metals for which substitutes do not yet exist.

The use of Cellophane for wrapping and protecting foods is so recent as yet to be regarded as almost miraculous. A somewhat analogous development is that of plastics to displace steel and wool for hundreds of purposes, ranging from rough packing cases to furniture and to certain works of art. The raw materials of which plastics are made fortunately are abundant and widely available.

Lest it be assumed that there are fairly satisfactory substitutes at hand or foreseen for every material now used by civilized men, one element should be mentioned that appears to be almost, if not quite, indispensable for very important purposes. It is of more importance than all the gold buried in Kentucky, than all the diamonds that are used as ornaments or the cutting points of tools. It is silver. For what is silver uniquely used? The answer is for photography, and hence indirectly for all the science and art and records and industry that depend upon it. Fortunately silver is widely distributed over the surface of the earth in quantities abundant for the uses of photography. F. R. M.

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WHAT ARE THE FITTEST?

I. A MISCHIEVOUS FALLACY

By Dr. R. E. COKER

KENAN PROFESSOR OF ZOOLOGY, UNIVERSITY OF NORTH CAROLINA

Are fitness and ruthlessness equivalent? Man has long been distinguished from other animals by the development of language as one of the most important means of communication, and now he has devised such efficient methods of transmitting language that any sequence of words can be broadcast over the whole world to be received everywhere at almost the same instant. Never in the history of the world has there been such a plethora of words in print, in forums and committee meetings and everywhere all the time throughout the circumambient atmosphere. Words are intended to promote understanding and theoretically there should have ensued an equally unprecedented development of common understanding and cooperation among the peoples of the terrestrial globe. Yet there has probably never been a time when there prevailed greater divergence of thought among people or greater want of agreement in interpretation of words that are in daily use—ordinary words like *democracy, communism, freedom,* the *right to work* or *social order*.[1] It is a paradoxical situation: we have an unprecedented let-down of physical barriers to inter-communication and mutual understanding associated with a hitherto unknown state of conflict between nations and diversity of opinion concerning facts and principles of social relations. Instead of promoting general concert of thought and harmony of action, words seem to have contributed to confusion and to the instigation of human behavior worse than that of animals not blessed or cursed with the powers of language.

The trouble seems to be in the lack of words or in our capacity to ingest them, but rather in the capacity to *digest* the words we hear and read, that is to say, to use them intelligently, critically and honestly. We are perhaps becoming word-drunk.

In this article we consider a particular sequence of five words that once embodied a particular idea but that came to be used to convey another meaning, with consequences in behavior patterns that actually threaten the future of mankind. I refer to "the survival of the fittest," Herbert Spencer's translation of Charles Darwin's "Natural Selection." *Fittest* and *strongest* were never

[1] Merely for illustration, with no wish to be critical but rather with a truly inquiring mind, the writer would ask: Why in the minds of some is it a crime against democracy and a denial of freedom to require the payment of a dollar for the right to vote, and the very acme of democracy and sublimation of freedom to require a fee of twenty-five dollars, or much more, for the right to work or to vote on the conditions of work? Whatever may be right in either case, it seems only too obvious that we do not all use the same words with even approximately the same meanings.

intended to be synonymous terms in biology; or, to paraphrase, with apology for slang, fit'n'st and fight'n'st are not the same thing.

Naturally the question arises who is to say what these words mean and why may not the meanings attached to them by one group have just as much validity as those assigned by another? Well, those of us who are biologists are saved embarrassment in answering this question by the fact that those who misuse the term frequently say frankly, or imply, that they base their particular interpretation on its general biological interpretation. Since this alleged principle of perpetuation has recently been assuming greater and greater historical significance, biologists may fail in their responsibilities to the thinking world if they do not try to make clear to statesmen, historians and philosophers, to speakers and writers in general, either that they accept a common connotation or that the conventional use of the term "survival of the fittest" has not, and has never had, the sanction of those primarily occupied with analysis and interpretation of biological phenomena.[2] Biologists have indeed spoken out about this misconception, but, if we are to catch up with a wide-spread error, we may need to be more frequent and more vigorous in our educational effort with respect to a basic biological principle. Perhaps, in a way, while occupied with our own special business, we have let a false interpretation of biological thought go by default. It is indeed possible to give practical actuality to a false standard. You and I do not believe that successful banditry is a fair criterion of fitness to survive; but bandits can and frequently do make toleration or non-toleration of that mode of disorder a genuine test of survival. In this case the practice of banditry may properly be designated a pseudo-criterion and, under proper social conditions, it should affect the survival only of the few bandits, and that negatively.

[2] Even though a few biologists may have accepted the substitute definition of the term.

It is well known that a very common lay interpretation of "natural selection" or "the survival of the fittest" is identified with the supposed principle of "tooth and claw" or with the alleged "law of the jungle" promulgated by those who never saw a jungle. We all know that this interpretation by whole nations, not indeed by all citizens of any nation (for no principle of action is ever recognized by all whose action it governs), but at least by a large and effectively influential portion of some nations, has now made the supposed rule of "the survival of the fittest" in threat and combat the basis of national policy. We know, moreover, that such a definition is accepted by a great number of otherwise competent non-biological thinkers as well as by some who do very little or only second-hand thinking. The not uncommon linkage of international war and the principle of natural selection was painfully exemplified recently by a radio speaker who, in concluding a somewhat dramatic narration of war news, exclaimed: "What a pity that Charles Darwin was ever born!" Thus exposing an appalling ignorance of Darwin!

Origin of the term "survival of the fittest." The law of the survival of the fittest, for, properly conceived, it is a *law* and not a theory at all, necessarily involves no such notions as those just mentioned; indeed it may even cry out against them. What Darwin was attempting to do, as is well known, was to develop an acceptable theory of the origin of species. What he actually did was to assemble a prodigious store of observational data—facts that any one might verify by the use of one's God-given senses—to lay these facts on the foundation of certain broad and indisputable premises, and thus to construct a factual edifice which any one might

behold and employ in the search for an answer to the original question. Darwin himself was led to a particular sort of answer, this being the origin of species through *descent with modification,* with all plants and animals having universal kinship through common origin.

We are not concerned now with Darwin's answer but only with the premises and chiefly with a particular premise. The premises, which we have recently characterized as indisputable, are four. The first is the general principle of heredity—like begets like. No one disputes that. Of course, Darwin and his early followers could not know all that we now know about heredity or about variation or how they are so intimately related as to be merely different aspects of the same thing. We analyze heredity differently now in the light of knowledge gained since Darwin's time. We know that resemblances between parent and offspring are not every one to be regarded as falling within the technical category of inheritance; that is to say, as owing their origin to common descent. Yet the general idea of heredity is still admissibly sound: one does not have to be an evolutionist, a biologist or even a civilized man, to know that if you want a crop of corn you plant corn, not wheat; if you want hound dogs you breed hound dogs, not collies.

The second premise was described as "variation." This is a common word having more than one meaning, but here employed in one special sense. It is a fair presumption, however, that, when we speak of variation in connection with the origin of species, every one understands that we refer, not to variation in the sense of change, as when we speak of variable stars, but rather to differences between organisms, even between those having the closest kinship. No two are exactly alike.

As with heredity, so with variation in the special sense, we now, in the light of fuller information, analyze the differences between individuals differently from the way they were analyzed 75 years ago. We know that some of the differences are heritable in the sense that they have characterized ancestors and may be expected to reappear in the offspring regardless of differences in environment. We know that some features of structure or behavior can be accounted for through the conditions under which the particular animal has lived and may not be expected to reappear in the next generation, except as the progeny has similar environmental conditions, and that the same characters may just as likely appear in the progeny, appropriately environed, of ancestors that never displayed them because they had not had the environment necessary to bring out such qualities. We do not, of course, say that heredity has nothing to do with environment-induced characters, because we know it has. We observe, furthermore, that some variations have more significance than others for survival, for transmission and for contribution to evolutionary change. Nevertheless, no one denies the fact of variation or its general significance. To cite only a single example, every one knows, at least in a general way, about fingerprint identification and must realize that such a technique of identification would fail of its purpose if two men were exactly alike.

The third premise was that of *overproduction.* When we consider: that an oyster may liberate several million eggs in the course of its life, whereas, on the average, only one or a pair must ultimately survive; that a healthy oak in its long life may produce a million acorns; that some plant lice may have twelve generations a year at a hundred a generation, giving a total potential family from one plant louse of ten sextillion; when, with awareness of these and hosts of similar phenomena, we contrast the potentialities of infinite crowding with

the obvious fact that populations remain relatively unchanged throughout the centuries, we can not fail to recognize the general prevalence of overproduction. For every kind of animal or plant, potentialities vastly exceed actualities so far as populations are concerned.

We are thus led inevitably to the *fourth* premise. Since mass elimination must be and is a part of the order of nature, the small proportion of the young of any species that survive and propagate are, as a general but not absolute rule, those that have some advantage for survival and reproduction. To say that organisms possessing some advantage for survival and reproduction have no more chance of survival and self-perpetuation than those which are disadvantaged is to utter plain nonsense. An apology may be required for treating this question in so elementary a way, but one is continually surprised to find those who think of the survival of the fittest as a theory rather than an axiom. All that the "survival of the fittest" means, or was ever intended to mean in biological thought, is that those best fitted to survive under the prevailing conditions will, by and large, be those that survive and reproduce. You may not like it, but you can not change it. It is good biblical doctrine; "He that doeth these things shall not be moved"; "the way of the ungodly shall perish"; These "shall have everlasting life," those "shall be cast into outer darkness." In any religious, ethical or scientific system it is conceived that those who measure up to existing standards endure, those who do not are lost: there are criteria of survival, whether fixed or changing.

Who are the fittest? The real question arises *not* as to the principle of the survival of the fittest, but rather as to the qualities that make for fitness to survive, to populate the earth and to progress, that is to say, to grow progressively in the characteristics that have demonstrated fitness. Here we enter into the realm of opinion, and opinions will generally be based upon observation, inference, logic and, to be sure, in no little part, where the survival of man is involved, upon a reasonable faith; for it is another characteristic of man that he has ideals and faith, although the effect of his faith on his behavior in a group is most variable. With respect to mankind there may be diverse theories as to the conditions of survival, but it seems clear that any and all opinions fall necessarily into one of two opposing groups, and it may make a great difference what type of opinion any great group of people has; because man is again distinguished from lower animals by his notable capacity to modify his behavior or to have it modified under the influence of abstract opinions. It is really important, therefore, that actual or expressed principles of action be critically examined and appraised for their potentially good or bad effects on human behavior and on ultimate human welfare.

There is, for example, the expressed opinion that survival is best assured by aggressive combativeness carried even to the extreme or unscrupulous and merciless brutality. The behavior pattern governed by this theory of action has even been alleged to be a direct corollary of the theory of progressive evolution through natural selection. It might take us too far afield to go now into the facts and arguments which would establish the complete fallacy of such an allegation. Darwin needs no defense; but, so that the thoughtless ascription to him of such a conception of the conditions of survival and evolution may not go by default, I quote a few sentences from his book entitled "The Descent of Man." In this book he suggests (p. 79) that, had man been derived from "an animal possessing great size, strength and fe-

rocity," he "would not perhaps have become social; and this would most effectually have checked the acquirement of the higher mental qualities, such as sympathy, and the love of his fellows." A compensatory advantage for want of strength and speed he finds in "his social qualities, which lead him to give and receive aid from his fellow man." Again he says (p. 142, edition of Collier, 1900):

> The moral sense perhaps affords the best and highest distinction between man and the lower animals; but I need say nothing on this head, as I have so lately endeavored to show that the social instincts—the prime principle of man's moral constitution—with the aid of active intellectual powers and the effects of habit, naturally lead to the golden rule, "As ye would that men should do to you, do ye to them likewise;" and this lies at the foundation of morality.

Darwin did not overlook the fact that man has been socially cooperative in inter-tribal combats, or the fact that man has never attained any degree of perfection as a social organism, but rather "man still bears in his bodily frame the indelible stamp of his lowly origin," and, by implication, also in his social frame. According to Darwin, man owes his civilization in no small part to being social, cooperative and kindly. It may be that he was all wrong in this opinion, or that he overemphasized the social qualities, but at least it is nonsensical and libelous to ascribe to him a view that is the exact converse of the one he has so well expressed.

We have a theory that the necessity of survival makes imperative a habit of aggression, subjugation and exploitation, and we have what may be called the Darwinian view, or the biological contention, that man has attained his present state of development primarily through his social, cooperative and altruistic qualities. In describing the latter concept as "the biological view" it is not meant to imply that it is held exclusively by biologists, or that it was originated by them, but merely that it is the view which arises inevitably from the contemplation of biological phenomena by those directly concerned with the social behavior of animals. The broad and fundamental significance of cooperation in all kinds of animals is so large a subject that it would be impossible now to go into it extensively, but others of greater competence have already done so, as Kropotkin, Patten and Allee, and many others. There may be added here a suggestion of the fact that the great majority of animals never apparently set out to exterminate or subjugate their own kind. I wish that some proponents of the Germanic interpretation of "the survival of the fittest" would point out a few cases in nature where animals do this. The few groups of ants that have the practice of enslaving ants of different species offer no exception to the rule. The most successful of nature's experiments in production of a diversity of kinds and large populations is found among the insects and their relatives, which almost never engage in intra-specific warfare. The moths, the butterflies and the birds that come so frequently and often so delightfully to our attention offer conspicuous examples of survival in numbers while living without the urge to destroy or to subjugate others of their kind.

I wish we had space to consider the implications of the familiar struggle for existence, the combats for mates and the predator-prey relationships which, by the way, are usually mutually beneficial to the species involved. The reader may guess that this writer does not hold with a Chinese philosopher who characterized the lion as wicked because it fed upon other animals, but rather with the Hebrew philosopher who heard the "young lions roar after their prey and seek their meat from God." It is conceded that one so inclined may argue from the predator-prey relationships in

nature that there is justification for any people who feel it to be in the interest of their well-being to enslave others. One may make such an extension, but, in doing so, enters a realm of opinion or erects a personal social theory, and obviously does not follow an inevitable path of logic in the field of biological data. It is argument by analogy, and analogies are suspect.

On the one hand, then, there has been the theory of survival through aggression and the exercise of brute force, and, on the other, until recently at least, a wide-spread tendency to give lip service to the assumed superiority of the so-called higher qualities of cooperation, justice, mercy, honor and brotherly love. In contrast to the dogma that "might makes right" the Golden Rule has been taken as an ideal of perfection. No one has denied the value of this rule as a standard in human relations, although few may have practiced it with any high degree of fidelity.

Now with the choice between principles of cooperation and mutual helpfulness on the one hand and of selfish aggression on the other, there is little doubt as to what would be the answer of almost every one of us. Furthermore, I believe there is not the shadow of a doubt but that, in the long run, survival for groups of men will be the reward of those who have the greatest capacity for social organization, whose behavior best exemplifies the ideal of joint action for the common good rather than that of exploitation for the assumed good of a favored few, and who have the will and the virility to maintain an endurable order. I am not a historian but I am strongly inclined to the belief that history supports this conviction. The career of the human race is indeed a conspicuously chequered one. War for subjugation, exploitation, dishonesty, brutality and other illustrations of assumed disreputable behavior have always been more or less in the order of the day. But, at the same time, and at *all* times, there have been notable displays by individual and groups, of what we are pleased to call the *humane* qualities, finding effect in religion, in education, in legislation and sometimes in business or in just plain everyday human relations. Old-time books of history emphasized wars, robberies, exploitations and breakings of faith, with only incidental allusion to the social and moral phenomena characterizing the periods under consideration, and this sometimes in small-print appendixes to chapters; hence the aptness of the saying, "Happy is the people that has no history!" Such histories must have been wrong, for human societies could not at different times have progressed to such advanced stages as have repeatedly been realized had not the constructive forces generally predominated over the destructive ones.

Could great cultures have developed without some measure of dominance of energies directed toward justice and human welfare over energies directed at subjugation and exploitation? And have not declines of empires begun when the balance was reversed? Rome engaged in conquest but also in the improvement of human relations with the development of a practical science of jurisprudence that had no equal then or for a thousand years after. Its broad empire rested in part upon aggression, but also in part upon the fact that substantial numbers of people lived better under Roman rule and had some participation in the rule. It was not the loss of an urge to aggression or the decline of combat-effectiveness in the Praetorian Guard and other armies that undermined a great empire; it was rather the social disorganization of the whole state, the going wild of the spirit of survival through conquest, conquest of foreign peoples and of domestic rivals, that progressively weakened and destroyed a

great empire. An unending series of struggles that pitted group against group, leader against leader, army against army, not in argument and rivalry for moral and political support, but in the false tactics of "tooth and claw," sapped the power that had rested upon cooperation and a considerable measure of respect for order and justice. The British Empire has engaged in conquest, but unquestionably its power and its persistence have derived more from what it has given than from what it has taken. Remove from its contribution to history the ideals and the practices, imperfect of course, in respect to liberty and justice, and Britain would be as much an empire as Roumania or Bulgaria.

We anticipate the reply: "Granted, but had Rome and Britain not engaged in conquest they might have been as great empires as Denmark and Sweden." In referring to great societies that developed in the past it has not been meant to imply that, under the conditions of the times, their greatness stemmed from one cause alone, even if we may see one form of behavior contributing in greater measure to the rise and maintenance of imperial greatness and another taking ascendency in the wane. To me it seems a somewhat academic question whether war, pestilence, famine, infanticide and human sacrifice were once useful and necessary to the control of populations and the effective organization of society. The past is instructive but not a complete guide for the future. Conditions change and man, the most adaptable of all creatures, makes new and unexpected adjustments. If one's grandfather was a wealthy philanthropist of high social prestige, who was finally hanged for having been a horse thief, it does not follow that to attain wealth and prestige one should begin by being a horse thief. If I had the problem of restoring the Roman Empire I should think it important to distinguish carefully between the behavior which led to real greatness and that which contributed most to the fall, a distinction which Mussolini has not seemed careful to make.

The plain fact is that man is an extraordinarily imperfect social being. No one can take a candid objective look at the human species in comparison with others and not see in our own kind maladjustments to social life that have no real parallel in less highly socialized species, displays of "brutishness" that can not be matched in the behavior of lower animals. What animal species would find continued delight in cruelties to its own kind that serve no genuinely useful purpose? And human history abounds in such cruelties. What animal would deliberately choose the most prolonged and excruciatingly painful modes of torture and execution of their fellows as is recorded in the history of man, not in the past alone but in the very present? It is unfair to dumb brutes to describe some human actions as "brutish." Actions that characterize some types of men would more appropriately be called "human" than "brutal" or "beastly"; but we much prefer to call them "inhuman," thus saving our self-respect without insult to wild beasts. Doubtless the explanation of "man's inhumanity to man" is to be found in the fact that the possession of greater capacity for social control carries with it the greater capacity for social disorder. The higher the ascent the greater the possible fall. Our most vicious qualities may not, after all, have "the indelible stamp of man's lowly origin," but may rather be abnormal distortions of the higher qualities we have gained. If it is not a fallacy to say that *inhumanity* (in-*human*-ity) is ingrained in *human* beings, it is at least a contradiction in terms.

It is desirable to think of this distinction because it is apparent that some of man's vicious qualities, whether ingrained or not, armed as they may be

with modern weapons and means of destruction, may bring about a real degradation of human society. It is becoming increasingly necessary that the expressions of social maladjustment involving whole nations should be brought under control if such control is within the possibilities, and we shall consider that question farther on. Fortunately, as has been previously suggested, man has the capacity to change patterns of behavior under the influence of ideas and ideals and to control a minority of misfits, comprising those who, through mental or moral obliquity, or through misconception of the requirements for survival, have established pseudo-criteria to threaten human society as a whole. The real criterion for mankind is not that which any individual or group chooses to set up, but is rather the willingness of people in general to endure certain modes of behavior and the capacity for effective cooperation in maintenance of a tolerable world order. We preach and we respect toleration, but there develop conditions in which toleration becomes a fetish and a large and crushing measure of intolerance is the only salvation.

It should be apparent that under any free working of the alleged principle of survival of the strongest and most combative, there could be no survival. If the stated criterion were adhered to there would finally be one man, who could not live indefinitely. Quite obviously survival is assured only when there is agreement among a large number or a few on some policy of "live and let live." The ultimate criterion of survival would be a conception of social order or, at worst, an unconscious surrender to the necessity for such. At what stage in the condition of disorder the acceptance of the valid criterion takes effect, and the extent to which there is partial or complete subordination of the initial criterion (the pseudo-criterion), will vary with historical time, with place and with the state of development of human culture. Consequently, we have, under different conditions, a dominant tribe or federation of tribes, a Babylonian or Roman empire, a ruling class, ecclesiastic, patrician or proletariat, perhaps some future empire or federation, or conceivably we may yet have—who knows?—a human empire with rights and privileges not restricted to Germans, Japanese, British, Russians or Americans, not vested in priests, nobles, capitalists or laborers. The last concept seems idealistic beyond the fondest dreams of practicability, but, unless I mistake the signs, necessity will not be long in driving us farther in that direction than we have ever dreamed of going. Do we not need an "esprit du corps," that applies to a much larger "corps"—a spirit of loyalty to our kind conceived more broadly than we yet have conceived? The question is asked *realistically* rather than idealistically; for we may be *compelled* to face it, and very soon. In the continuation of this discussion, let us try to see what biological orientation, if any, can be found in a condition of social disruption which has no real precedent in human or biological history.

(To be concluded)

INFANTILE PARALYSIS: THE INCITING AGENT AND SPECIFIC SERUM TREATMENT[1]

By Dr. EDWARD C. ROSENOW

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THE deplorable nature of the handicap, paralysis, and the high death rate which often results from attacks of poliomyelitis that occur so frequently at the very onset of life have made this disease—aptly named infantile paralysis—perhaps the most dreaded of all the infectious diseases. Its prevention and cure have been one of the major problems of medical science ever since 1840 when it was first recognized as a distinct disease. The solution of this problem has been beset with difficulties inherent in the very nature of the disease and its causative agent. Poliomyelitis often occurs in sporadic and epidemic form far remote from other cases. The symptoms and signs at the onset of illness, before the deplorable paralysis occurs, are usually not sufficiently characteristic to be recognized readily, thus making early treatment difficult. The discovery in 1909 that the causative agent is a filtrable virus was the first great advance in the study of the problem. Bacteriologic studies which were yielding important results at that time were dropped forthwith because it was thought—and quite naturally—that any organism which could be seen and which could be cultivated on artificial culture media could no longer be considered as having significance in poliomyelitis. For seven years, 1909 to 1916, intensive studies on the mysterious virus, made under the most favorable auspices and by the greatest of scientists the world over, revealed important information as to the nature of this dread disease, the manner or route by which virus gains entrance into the body, and its specific localization in that part of the nervous system on which locomotion or function of muscles depends.

During this same period, studies of my own on the behavior of pneumococci and streptococci, the causes of different disease entities, yielded a mass of evidence indicating their mutability and their ever changing character when placed under diverse conditions. These basic observations have been corroborated since in essential respects by various investigators. As changes of size, shape and growth requirements were induced by subjecting these organisms to stress and strain in the test tube and in animals, under conditions in which relatively few organisms survived, marked changes of virulence and localizing power occurred. Moreover, streptococci that had been isolated freshly by special methods, and filtrates of these cultures, often produced extremely specific effects on intravenous injection into animals. This was especially true in experiments with the streptococci isolated from infected teeth and tonsils and from cerebrospinal fluid of patients in studies of a very painful disease—shingles or herpes zoster (acute posterior poliomyelitis). Herpes, or blistering of the skin in the involved area, associated with severe pain due to localization and lesions in the posterior or sensory roots of the spinal nerves and posterior columns of the spinal cord, was produced experimentally with the

[1] Names of authors and references to contributions in studies of poliomyelitis will not be given in this paper since they have been recorded elsewhere. Details and statistical figures of many experiments have been recorded in the medical literature and for the sake of brevity will be omitted, in large part, in this report. In all instances the number of experiments was sufficiently large to warrant the conclusions drawn.

living streptococcus and with filtrates of active cultures.

These and other similar observations led to the birth of a new concept regarding the nature of the inciting agent of poliomyelitis—that perhaps streptococci having specific affinity for the cells of the spinal cord which control locomotion, and other distinctive properties, might have causal relation to this disease, despite the fact that the inciting agent had been shown to pass through porcelain and other bacteriologic filters. Filtrability of inciting agents of disease and inability to demonstrate organisms in filtrates by the methods then available, I reasoned, did not imply necessarily that viruses were distinct entities wholly unrelated to bacteria, as was then and is still usually considered.

Opportunity was afforded me to put to the test this basic concept through the auspices of the Mayo Foundation and the New York Hospital. With mingled feelings of fear and high hopes, the opportunity was embraced during a small outbreak of poliomyelitis in Rochester, Minnesota, and during the large epidemic of poliomyelitis in New York City in 1916.

Isolation and Demonstration of the Streptococcus

By special methods used successfully in a study of other diseases and described in the medical literature, a streptococcus was isolated from the nasopharynx or tonsils in each of seven cases of poliomyelitis that occurred in Rochester, and consistently from the nasopharynx and tonsils of many children who survived, and from emulsions and sometimes from filtrates of emulsions of brain and spinal cord of nineteen persons who had succumbed to poliomyelitis during the epidemic in New York. Excitement was high during the course of these studies as cultures continued to yield the streptococcus, always of the same type—often extremely pleomorphic, that is, large and exceedingly small forms sometimes in the same chain—and as, in turn, young cultures of the freshly isolated streptococcus yielded specific results in inoculated animals. Symptoms and lesions such as occurred in these studies were almost never encountered during the course of many similar experiments, before and since, after identical inoculations of streptococci isolated in studies of diseases other than poliomyelitis. Similar results were obtained by several other workers in consequence, but despite these striking results the bacteriologic study of this disease by adequate methods has not again been considered seriously by other investigators in this field. There is perhaps no better illustration in all medical science of the profound influence which point of view or concept has had on the solution of a problem than is given by the diverse studies on poliomyelitis.

Having consistently isolated a certain type of streptococcus in epidemic poliomyelitis as it occurred spontaneously in human beings, my co-workers and I immediately applied our methods to a bacteriologic study of experimental poliomyelitis in monkeys induced by the intracerebral inoculation of emulsions or filtrates of emulsions of spinal cord tissue of persons or monkeys that had succumbed to poliomyelitis. The same type of streptococcus was isolated in these studies. Moreover, the streptococcus, in the form chiefly of diplococci of varying size, was demonstrated consistently by us and by others in the lesions of the spinal cord of patients who had succumbed to poliomyelitis and of monkeys that had died from experimental poliomyelitis, and was proved absent in sites remote from lesions.

Preparation and Use of the Poliomyelitis Antistreptococcic Serum

On the basis of these additional results and the absence of any highly effective method of treatment of poliomyelitis, we

immunized horses, at first with freshly isolated strains of the living streptococcus from patients, and later, after the epidemic had subsided, with strains freshly isolated from time to time during the period of immunization (seven months) from the spinal cords of monkeys that had succumbed to experimental poliomyelitis after inoculation of virus. At the end of the period of immunization the antistreptococcic serum, in extremely high dilutions, was found to agglutinate specifically the poliomyelitic type of streptococcus, which is an accepted measure of antibodies or of curative properties usually present in antiserums. Intravenous and intramuscular injections of the serum protected rabbits against inoculation of the streptococcus and protected monkeys against inoculation of poliomyelitic virus. The need for a curative serum was especially great then, as now, because even though convalescent poliomyelitis serum were effective it could not solve the problem, since the disease would have to continue to occur with its dire consequences to assure a supply of serum.

The first opportunity to use the antistreptococcic serum in the treatment of patients occurred in the summer of 1917 during an epidemic of poliomyelitis in Davenport, Iowa, and surrounding country and nearby towns. The results from its intravenous injection in the treatment of fifty-eight patients suffering from poliomyelitis were most gratifying. The findings, the amount of serum administered and the effects noted in each case treated were reported in detail at that time. It was truly encouraging to see patient after patient respond to the injection of this newly developed antiserum. Physicians, whose patients were seen in consultation and treated in their homes with the serum, were as impressed as we were. Diagnosis was made on the clinical history, physical examination and characteristic findings on immediate examination of the cerebrospinal fluid at the bedside. The serum was administered at once after the diagnosis was established.

The type of the disease in this epidemic was unusually severe. A high incidence of paralytic cases occurred. The mortality rate in the untreated group of twenty-three patients was 35 per cent. Of the fifty-eight patients receiving the serum, ten (17 per cent.) died. Excluding seven of the fatal cases in which the patients were practically moribund at the time of the first serum treatment, there were three deaths (6 per cent.)—in all of which the serum treatment was begun late—among fifty-one cases in which the serum could possibly have beneficial action. Paralysis did not develop in any of nineteen patients to whom serum treatment was given before its onset, and all nineteen patients recovered. Extension of paralysis rarely occurred among patients who recovered and in whom paralysis, often far advanced, was present at the time of the first serum treatment. Patients in the early stages of the dreaded bulbar type of the disease, with early difficulty in swallowing and breathing; patients having the ascending spinal type with almost complete flaccid paralysis of all extremities and with difficulty in breathing due to involvement of the nerve centers of the muscles of respiration, and even patients in the early stages of partial or complete coma often responded favorably to administration of the serum.

In order that the readers of this account may understand better the significance of what has been found, and that they may not forget the human side of science, I can not but report in some detail the happy result obtained in the case of one large family group on a farm in which two sisters, four and eight years of age, were stricken with this disease. Typical symptoms of poliomyelitis, consisting of nausea and vomiting, fever,

tremors and spasms of muscles and mental apathy, had begun two and three days, respectively, before I saw the patients. At the time of serum treatment the temperatures were 103.2 and 102° F., respectively. The tonsils were large, infected and congested, the throats were red, and the cervical lymph nodes were palpable. The pulse rates were extremely rapid. There was rigidity of the neck in both and flexion caused pain in the back. Both patients had fine and coarse tremors of the fingers and hands and were tremulous and ataxic. Physical examination of the patients and examination of the cerebrospinal fluid revealed findings typical of poliomyelitis.

Ten cubic centimeters of the poliomyelitis antistreptococcic serum was given intravenously to each child. Both were better the following day. Tremors and twitchings of muscles and the mental apathy had disappeared. There was no paralysis. The respective temperatures were lower and the rigidity of the neck and the knee reflexes were less marked. The injection of serum was repeated in each case and again the following day. The temperatures dropped promptly to normal and all symptoms disappeared. Both children recovered without paralysis, as shown in the photograph (Fig. 1). I have never seen two children of the same family who contracted poliomyelitis recover untreated without paralysis developing in at least one. Often the first one stricken succumbs or severe paralysis develops and the other recovers but usually not without some degree of paralysis. Sometimes both have succumbed to the disease. Similar gratifying results have since been obtained following serum treatment of two or more patients in family groups.

As has been indicated, the antiserum used intravenously with such striking results was prepared by inoculation of horses, at first with suspensions of streptococci freshly isolated from patients, and later with streptococci freshly isolated from the spinal cords of monkeys that had succumbed to poliomyelitis after inoculation of virus. In order to make more practical the preparation of antiserum, a method for the preservation of specific antigenic or immunizing properties of the streptococcus throughout the period of immunization of horses was searched for. It was found that by placing the freshly isolated streptococci in very dense suspensions in glycerin (2 parts) and 25 per cent. solution of sodium chloride (1 part) and keeping these in the refrigerator, antigenic specificity was preserved almost indefinitely. All subsequent batches of antistreptococcic serum used for treatment were prepared by diluting these dense suspensions as needed for injections throughout the period of immunization. The experimental and clinical results obtained by us from the intramuscular use of the antiserums prepared in this way, by physicians to whom the serum was sent gratis for study on request, and by physicians who have used the commercially prepared antiserum independently in different epidemics of poliomyelitis since, have been comparable with those obtained in 1917. A summary of results of these studies is given in Table 1.

The cases summarized in Table 1 represent published and as yet unpublished reports. I have studied the effects of the serum in treatment in altogether twenty different epidemics which have occurred since 1917 in different regions of the United States and in Cuba, in four institutional outbreaks and in many cases that have occurred in isolated family groups. The two most important consequences of this disease—death and residual paralysis—were found consistently lower, usually much lower, in the cases in which serum was used than in the control cases that occurred in the same epidemics.

TABLE 1

SUMMARY OF RESULTS FROM THE TREATMENT WITH POLIOMYELITIS ANTISTREPTOCOCCIC SERUM OF PATIENTS SUFFERING FROM ACUTE POLIOMYELITIS

Cases studied by:	Condition of patient at time of first serum treatment	Cases	Deaths		Cases*	Severe residual paralysis	
			Number	Per cent.		Number	Per cent.
Rosenow and co-workers, and physicians to whom serum was sent on request	Before onset of paralysis ...	487	16	3.3	460	9	2.0
	After slight to moderate paralysis	696	42	6.0	621	20	3.2
	After severe paralysis	771	134	17.4	635	150	23.6
	Total	1,954	192	9.8	1,716	179	10.4
	Controls, cases in which patients were not treated with serum, that occurred during the same epidemics	711	176	24.8	540	178	33.0
Other physicians, independently	Cases in which patients were treated with poliomyelitis antistreptococcic serum ..	710	60	8.5			
	Controls, cases in which patients were not treated with poliomyelitis antistreptococcic serum, that occurred in the same epidemics	2,026	407	20.1			
Total cases in which patients were treated with poliomyelitis antistreptococcic serum		2,664	252	9.5			
Total control cases in which patients were not treated with poliomyelitis antistreptococci serum		2,737	583	21.3			

* This group consists of those cases in which data as to end results were obtained.

As indicated in Table 1, the mortality rate in the groups receiving the serum in the early stages of the disease was reduced to an eighth and a fourth, and incidence of residual paralysis to about a sixteenth and a tenth, respectively, of the corresponding rates of patients who were not treated with serum. Even the patients that received the serum first after severe paralysis had occurred fared better than did the controls.

In most of the cases studied by me the patients were seen at home in consultation with the family physician. The serum was administered at once after the diagnosis had been established by spinal puncture and immediate examination of the cerebrospinal fluid, and not first after the patient had been subjected to fear and other stresses and after loss of precious time incident to hospitalization. The diagnostic skill of the family physician, as I have seen it, in recognizing and treating the unusual in illnesses as they occur in family units is truly commendable. The results reported to us by physicians to whom the serum was sent, and of those who reported results independently, were strikingly similar to ours. All who had opportunity to treat numbers of patients in early stages of the disease reported enthusiastically on the results obtained. The beneficial action noted at the bedside is indicated strikingly also in Table 1. Thus, of the total of 2,664 patients who were treated with the serum, 252 (9.5 per cent.) died, which is in sharp contrast to 583 deaths (21 per cent.) among 2,737 control cases that occurred in the same epidemics but in which the serum was not used.

Results from the use, under controlled conditions, of various batches of the poliomyelitis antistreptococcic serum in the treatment of experimental poliomyelitis in monkeys were also strikingly favorable. Thus, of a group of monkeys treated with different batches of serum after onset of paralysis, 46 per cent. died, whereas of a comparable group of control monkeys that had received inoculations of the same virus and that were

not treated with the serum 83 per cent. died.

To show that the beneficial effects obtained in treatment of poliomyelitis with the antistreptococcic serum were due to specific antibodies in the serum, virus was treated in the test tube with the freshly obtained immune horse serum, and as a control with normal horse serum, before it was inoculated into monkeys, in the hope that the virus might be rendered ineffective by the immune serum. Thus, death from poliomyelitis occurred in only 27 per cent. of monkeys inoculated with virus that had been treated with the immune horse serum, in contrast to a mortality rate of 79 per cent. of monkeys that had received the same virus but after identical treatment with normal horse serum.

The results from the therapeutic use of the serum in human beings and in monkeys, reported on from time to time in the medical literature and as summarized here, would have led, it is believed, to the general adoption of this specific serum treatment of poliomyelitis if the inciting agent had not been shown to be filtrable, and if all requirements showing causal relation of the streptococcus could then have been fulfilled. The latter, unfortunately, were not forthcoming until recently. It is, therefore, considered imperative to indicate briefly, step by step, the results obtained in further attempts to fulfill these requirements.

Further Results Indicating Causal Relation of the Streptococcus

The streptococcus has been isolated consistently from various sources, such as nasopharynx, stool and cerebrospinal fluid of persons ill with spontaneous poliomyelitis, and from brain and spinal cord of those who had died, from nasopharynx of contacts and noncontacts within epidemic zones of poliomyelitis, and from cerebrospinal fluid, brain and spinal cord of monkeys ill with experimental poliomyelitis induced with virus. Control cultures made under identical conditions almost never yielded streptococci. By our methods, and never by those usually employed, the streptococcus was isolated from about a third of the filtrates of emulsions of spinal cord and brain of persons and monkeys that had succumbed during the acute stage of the disease. In short, it was possible to isolate this specific type of streptococcus from the very tissues and other materials in which virus has been demonstrated most often, whereas this was not possible from tissues shown to be free from virus.

It is a well-known fact that virus present in brain and spinal cord of persons and monkeys that have succumbed to poliomyelitis remains alive for a long time after preservation in 50 per cent. glycerin. Therefore, it was thought that if the virus and the streptococcus were related, the streptococcus should also survive such storage. Accordingly, cultures were made at intervals from, and monkeys were inoculated with, emulsions of brain and cord tissue that had been preserved in this way for a long time. It was found, during the course of many experiments, that the streptococcus was approximately as resistant as the virus. The incidence of isolations of the streptococcus and the successful production of poliomyelitis in monkeys with the virus, were highest soon after preservation and became progressively less, roughly in proportion to the duration of preservation, but isolations of streptococci and "virus takes" were successful for as long as four years in some instances.

A Test for Susceptibility to Poliomyelitis

The need for a test of susceptibility was obvious and I reasoned that if the streptococcus really was of etiologic significance in poliomyelitis, then cutaneous

reactions eighteen to twenty-four hours after intradermal injection of the heat-killed streptococcus in appropriate amounts should be greater in susceptible than in immune persons. This was found to be strikingly true as large numbers of persons were tested with a suspension of dead poliomyelitic streptococci and with a similar suspension of arthritic streptococci used as a control.

Positive reactions were obtained in fifty-two (87 per cent.) of sixty persons tested at the onset of attacks of poliomyelitis, in contrast to twenty-eight (13 per cent.) of 209 persons tested during convalescence, or who had recovered from poliomyelitis two weeks to many years before. The incidence of reactors to the poliomyelitis test according to age groups among persons who had not had poliomyelitis was most interesting and was roughly proportional to the age incidence of the disease. Of 614 children from one to five years of age, 430 (70 per cent.) reacted; of 489 children from six to ten years of age, 364 (74 per cent.) reacted; of 445 children from eleven to fifteen years of age, 277 (62 per cent.) reacted, and in 1,125 persons sixteen years of age or more, 282 (25 per cent.) reacted. There was little variation of incidence of reactors (10 to 25 per cent.) to the arthritis antigen in the different groups.

Skin tests were also made on well persons of different age groups at a foundlings' home during an epidemic of severe poliomyelitis affecting chiefly infants and young children—truly infantile paralysis. On intradermal injection, the streptococcal suspension prepared from strains isolated from patients in this epidemic produced reactions in highest and significant incidence in infants and young children, the very age groups chiefly affected in this epidemic, whereas a comparable suspension of streptococci isolated from patients in an epidemic in which older children and young adults were chiefly affected produced reactions in highest and significant incidence in older children and young adults.

Moreover, in other studies it was found that adults who reacted markedly to the intradermal test reacted progressively less and became negative when the intradermal test was repeated after four weekly subcutaneous injections of a vaccine prepared with the freshly isolated strains of the streptococcus. In one study the serum was obtained from the blood of five persons before vaccination when the skin reactions were strongly positive, and after vaccination when the skin reactions had become negative. The serum obtained before vaccination did not, and that obtained after vaccination did, neutralize virus.

The male sex is known to be more susceptible to poliomyelitis than the female sex. In accord with this fact, among male students the incidence of reactors to the poliomyelitis intradermal test dropped from 23 per cent. during an epidemic of poliomyelitis to 14 per cent. six weeks later, whereas among female students the incidence dropped only from 19 to 17 per cent. There was no change in incidence of reactors among students tested as controls during the six weeks' period at a neighboring college in which no cases occurred.

Protection of Monkeys with Streptococcic Vaccine

It was felt that if monkeys could be immunized with vaccines prepared with the poliomyelitic type of streptococcus so that they would be immune to intranasal inoculation of highly virulent poliomyelitic virus, there would be at hand another important link in the chain of evidence that the streptococcus is causative. This we were able to accomplish. Thus, only 26 per cent. of monkeys that had been immunized with living or heat-killed streptococci ob-

tained in studies of poliomyelitis succumbed to poliomyelitis, in contrast to 84 per cent. of a comparable group that had not been immunized and that received the same virus. Immunity was shown to last for at least one and a half years. In monkeys that received similar injections of vaccines prepared with streptococci obtained in studies of arthritis no protection was afforded. The basic requirements for the use of this type of vaccine for the immunization of persons were, therefore, fulfilled. However, since the number of cases of poliomyelitis that develop in epidemics is small in proportion to the total population, and at least 2,000 persons would have to be immunized during epidemics to protect one person, this would be impractical and almost impossible.

Monkeys thoroughly immunized with the poliomyelitic streptococcic vaccine remained well after inoculation of poliomyelitic virus whereas in monkeys only partially immunized, symptoms and lesions of encephalitis instead of poliomyelitis developed, illustrating the ability of virus to change or mutate under stress, as do pneumococci and streptococci, in order to survive. Most interestingly, the streptococci isolated from the inoculated poliomyelitic virus were shown to be poliomyelitic in type, whereas the streptococci isolated from the brain of the monkeys that were partially immunized and in which symptoms and lesions of encephalitis developed following inoculation of poliomyelitic virus, were found to be encephalitic in type.

Diagnostic Tests for Poliomyelitis

The findings on examination of cerebrospinal fluid, while of great value in the diagnosis of poliomyelitis, are not always sufficiently characteristic to enable one to distinguish poliomyelitis from certain forms of encephalitis and tuberculous meningitis. Moreover, changes of cerebrospinal fluid from the normal do not occur until after penetration of the virus or streptococci into the nervous system. The need was therefore very great for a means of determining the type of infection at the very onset of suggestive symptoms, days before penetration by the virus or streptococcus of the nerve centers in the spinal cord. It should thus be possible to prevent paralysis and death of persons stricken, by therapeutic injections—at the very onset of symptoms—of a curative serum such as we have developed. Fortunately our studies yielded two relatively simple methods which make practical this possibility.

The precipitation test was made with the blood serums of persons and of monkeys by superimposing these serums on the poliomyelitis antistreptococcic serum in small test tubes and noting the occurrence of clouding at the interphase, or boundary between the two layers of serum, eighteen to twenty-four hours later. Clouding, or positive reaction, occurred in tests with fifty-six (85 per cent.) of sixty-six serums obtained from sixty-six patients during the acute stage (one to twenty-one days) of poliomyelitis, and in tests with only three serums (4.5 per cent.) of sixty-six persons who had been ill forty-two days or longer. The serums of a large series of monkeys obtained during the acute stage of poliomyelitis which developed after inoculation of virus, and the serums of a similar series of normal monkeys were subjected to the same precipitation test. Eighty-three per cent. of the serums of the poliomyelitis group and only 7 per cent. of the serums of the normal group gave a positive reaction with the poliomyelitis antistreptococcic serum.

It was found that during the acute stage of poliomyelitis the skin of patients gave an immediate (five to ten minutes) reaction at the site of intradermal injection of a minute amount of a 10 per cent. solution in saline of the

water-insoluble (euglobulin) fraction of the serum of horses that had been immunized with the streptococcus from poliomyelitis (Fig. 2), and that little or no reaction occurred following identical injections into well persons or persons ill with other diseases remote from epidemics of poliomyelitis. The idea at once occurred to me that this might prove to be the much needed and sought for, simple, early diagnostic test. Since first discovered in 1937, this test, checked with suitable controls, has proved to be highly specific as made on the skin of persons having poliomyelitis, and of well contacts and noncontacts, in altogether nineteen epidemics that occurred in widely separated cities or rural communities of the United States.[2] Fifteen independent observers who have applied the test have obtained similar results.

FIG. 1. SISTERS WHO RECOVERED WITHOUT PARALYSIS FROM POLIOMYELITIS AFTER ADMINISTRATION OF POLIOMYELITIS ANTISTREPTOCOCCIC SERUM IN EARLY STAGES OF THE DISEASE.

[2] Acknowledgment is here made to physicians, superintendents of hospitals, health officers, nurses and others who so generously cooperated in these studies.

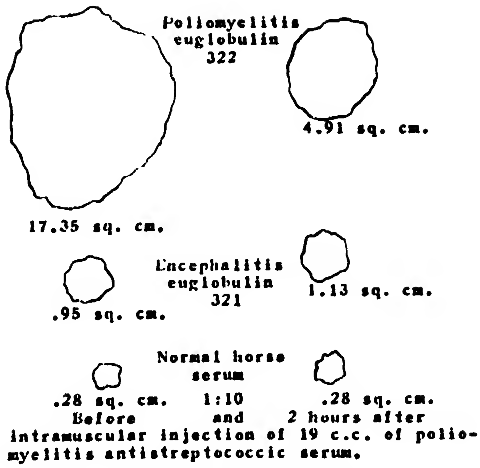

FIG. 2. TRACING OF ERYTHEMATOUS CUTANEOUS REACTIONS TO THE POLIOMYELITIS EUGLOBULIN AND CONTROLS, SHOWING MARKED REDUCTION IN REACTIVITY OF THE SKIN TO REINJECTION OF THE POLIOMYELITIS EUGLOBULIN FOLLOWING INTRAMUSCULAR INJECTION OF POLIOMYELITIS ANTISTREPTOCOCCIC SERUM IN A CASE OF ACUTE POLIOMYELITIS, SIXTH DAY. (× ½).

In ninety-two per cent. of 324 persons ill with poliomyelitis for from one to fourteen days cutaneous reactions, 5 sq. cm. or more in area, occurred to the poliomyelitis euglobulin. The average size in square centimeters of the erythematous reaction shown by patients during the acute stage of poliomyelitis was 8.7; by patients convalescing from poliomyelitis, 3.3; by well contacts, 4.2; by well persons within epidemic zones, 3.5, and by well persons remote from epidemics, 1.5.

A similar cutaneous reaction was found to occur in 90 per cent. of monkeys tested during attacks of experimental poliomyelitis produced with natural and laboratory virus (Fig. 3). No such reaction occurred in normal monkeys. Therapeutic injections of the poliomyelitis antistreptococcic serum into persons (Fig. 2) and monkeys during attacks of acute poliomyelitis caused the reactivity of both the skin and the blood serum to diminish or disappear

promptly as improvement of symptoms occurred.

In order to determine whether the cutaneous reaction obtained in persons and monkeys during attacks of poliomyelitis on intradermal injection of the poliomyelitis euglobulin was actually due to the presence of specific toxins of the streptococcus, monkeys were inoculated intracerebrally under ether anesthesia with large numbers of heat-killed streptococci obtained in studies of poliomyelitis and arthritis, respectively. In monkeys that had received the poliomyelitic streptococci flaccid paralysis developed associated with degeneration of motor cells in the spinal cord, and in those that had received the arthritic streptococci symptoms of arthritis and periarthritis developed. On skin testing these monkeys it was found that in those which received the poliomyelitic streptococci a specific cutaneous reaction occurred to the poliomyelitis euglobulin and in those inoculated with the arthritic streptococci the reaction was specific to the arthritis euglobulin. The monkeys that recovered after injection of the dead poliomyelitic streptococci resisted inoculation of virus, whereas those that recovered after injection of the dead arthritic streptococci succumbed to inoculation of virus.

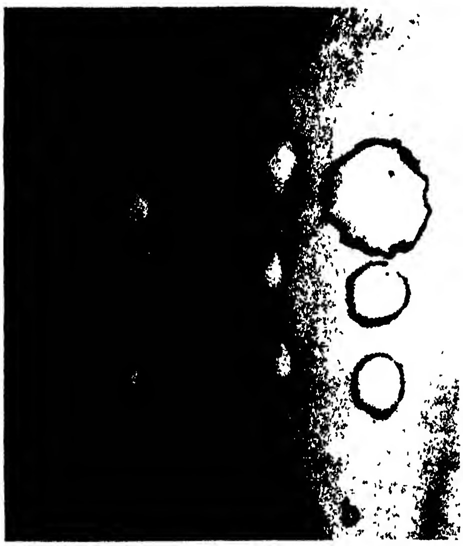

FIG. 3. CUTANEOUS REACTIONS IN A MACACUS RHESUS MONKEY ON THE THIRD DAY OF PARALYSIS FOLLOWING INOCULATION OF "NATURAL" VIRUS. (*a*) FIVE MINUTES AND (*b*) THIRTY MINUTES, AFTER INTRADERMAL INJECTION OF TWO BATCHES OF THE POLIOMYELITIS (*top row*), ENCEPHALITIS (*middle row*) AND ARTHRITIS (*bottom row*) EUGLOBULINS, RESPECTIVELY. NOTE POSITIVE REACTION TO POLIOMYELITIS EUGLOBULIN AND NEGATIVE REACTIONS TO ENCEPHALITIS AND ARTHRITIS EUGLOBULINS.

Experimental Poliomyelitis after Inoculation of Virus Produced with the Streptococcus

Despite the important fact that flaccid paralysis and other symptoms of poliomyelitis have been produced consistently experimentally in animals by appropriate injections of the freshly isolated streptococcus, certain valid requirements were not fulfilled as proof of causal relation of the streptoccoccus. The symptoms after inoculation of the streptococcus into guinea-pigs, rabbits and monkeys developed within twenty-four to forty-eight hours instead of after a week or ten days, as occurs after inoculation of virus. If virulence or dosage was high, death from progressive paralysis occurred in from two to four days, before typical lesions developed, and if the virulence or dosage was low, recovery occurred soon after slight to moderate paralysis had developed. Moreover, the disease could not be reproduced in series in animals, as is possible with virus, by the inoculation of emulsions or filtrates of emulsions of the spinal cord.

The attempts to reproduce in the monkey all requirements with the streptococcus, as such, were numerous and without success throughout many years, but not without encouraging results. Finally, by the use of a medium consisting of infantile tissue—an autoclaved suspension of chick embryos—in which

acid reaction does not develop from growth of the streptococcus, we succeeded in producing filtrable virus from the streptococcus. This was accomplished with four strains of streptococci isolated in studies of poliomyelitis, from which the possible presence of virus was excluded, and with two strains of streptococci isolated from sources other than poliomyelitis, but which had virulence and other properties resembling those of the streptococcus from poliomyelitis. Excitement was indeed high when on successive passage of experimental virus from monkey to monkey symptoms and lesions typical of poliomyelitis developed. After the experimentally produced virus strains were adapted to monkeys from repeated passages they resembled "natural" virus in filtrability and other essential respects, as determined during the course of many experiments. Monkeys that had recovered from attacks of poliomyelitis after inoculation of "natural" virus were found immune to inoculation of different experimental virus strains and their blood serum neutralized the experimental virus, or rendered it ineffective, under the same conditions as "natural" virus.

As a climax to these extensive studies, we succeeded in demonstrating microdiplococci, often in short chains, unstained, with the new scientific tool—the electron microscope (Fig. 4), and with the light microscope after special staining (Fig. 5), in filtrates of "natural" and the experimentally produced virus, and in filtrates of old cultures in the chick embryo medium in which virus had developed from the streptococcus. It was estimated that 1 c.c. of filtrate contained as many as 400,000,000 microdiplococci and that some of these approximated the postulated size of the virus particle.

The streptococci as seen in cultures, cerebrospinal fluid and lesions, and the microdiplococci as seen in filtrates of virus, show similar variations in size, shape and grouping and are similar antigenically, but are very different in their growth requirements. While our mediums have often sufficed for the isolation of the streptococcus phase from cerebrospinal fluid, from emulsions of spinal cord and other material containing virus, and even from filtrates in which only microdiplococci are seen, they do not suffice to grow or isolate the virus or microdiplococci as such. The living cells or other conditions supplied by the brain and spinal cord or other tissues of susceptible animals are necessary but as growth occurs of the virus—both "natural" and experimental—the streptococcal phase also appears, demonstrable, although often with difficulty, in cerebrospinal fluid as symptoms develop and in the lesions after death. The streptococcal form has been found highly antigenic and suitable for the preparation of preventive vaccines and curative antiserums. The changes of size of the streptococci from small to large (virus to streptococcus) and from large to small (streptococcus to virus) form without apparent change in antigenicity resemble the phenomenon of polymerization in which great altera-

FIG. 4. LARGE AND SMALL COCCI OVOIDS AND DIPLOCOCCI, SINGLE, IN CIRCLE AND IN SHORT CHAINS, RESEMBLING MICRO-ORGANISMS; REVEALED BY THE ELECTRON MICROSCOPE IN FILTRATES OF EMULSIONS OF THE SPINAL CORD OF A MONKEY THAT HAD SUCCUMBED TO "NATURAL" POLIOMYELITIC VIRUS. (UNSTAINED, 11,400).

tions of physical properties occur in certain substances without change of chemical constitution.

Summary and Conclusions

Throughout the many years in which my studies on poliomyelitis have been continued, concepts and facts were followed which resulted from leads suggested by experimental methods of trial and error. Inherent or acquired specific properties of the streptococcus, and at first of other bacteria, on isolation from the original source and as manifested in inoculated animals were considered of primary importance.

In addition to suggestive evidence which had been at hand for so long, some of which has been corroborated and extended by other investigators, including the striking beneficial action, in treatment, of the immune serum prepared with the streptococcus, convincing evidence indicating a causal relation of the streptococcus to poliomyelitis and the virus has now been adduced. Filtrable virus has been produced experimentally from streptococci and with it poliomyelitis has been produced many times in Macacus rhesus monkeys in series in the same way as with "natural" virus. Monkeys that had recovered from poliomyelitis after inoculations of "natural" virus were found immune to inoculations of the experimental virus and their blood serum obtained during convalescence neutralized the experimental virus. Microdiplococci—some approximating the postulated size of the virus particle—have been demonstrated in filtrates of both "natural" and experimental virus and in filtrates of old cultures of the streptococcus in chick embryo medium, the medium in which virus developed.

The immune serum which we and others have prepared in horses with the streptococcus has been shown to have

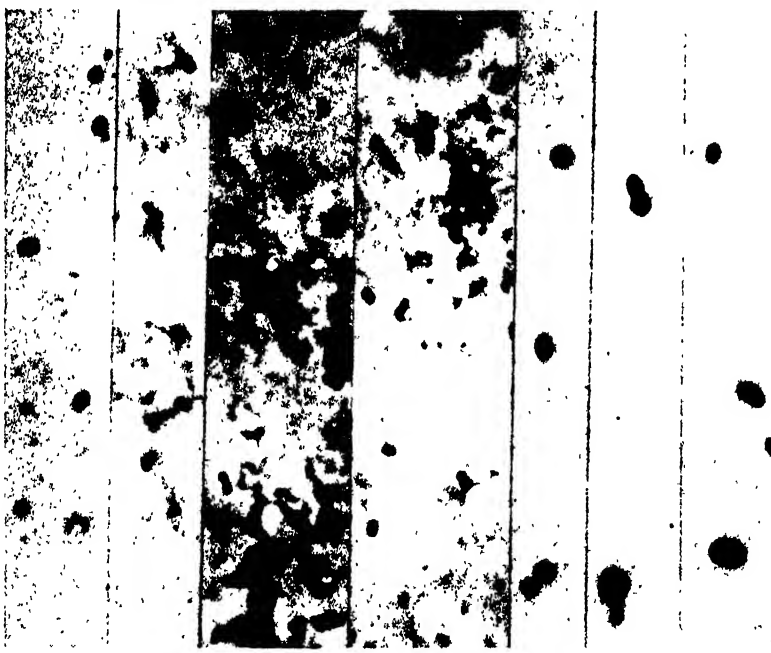

FIG. 5. COCCI, OVOIDS AND DIPLOCOCCI

SINGLE AND IN SHORT CHAINS, REVEALED BY THE ORDINARY LIGHT MICROSCOPE IN THE SAME FILTRATE REFERRED TO IN FIG. 4, AFTER SPECIAL STAINING. (×1,300).

diagnostic, preventive and curative action in treatment of poliomyelitis.

It is concluded that poliomyelitis is caused by a highly specific type of streptococcus and that what is now generally considered as virus is the small, filtrable microdiplococcus phase of the streptococcus. It is realized how contrary to current opinion these conclusions are, but the facts adduced permit no other interpretation. It is hoped that the methods and concepts which have led to these results, or better ones along similar lines, will be adopted generally, especially by those whose facilities and talents are far greater than mine, in order that the ravages of this most dreaded of diseases—infantile paralysis—may soon be brought under control.

TOTEM POLES: A BY-PRODUCT OF THE FUR TRADE

By Dr. MARIUS BARBEAU

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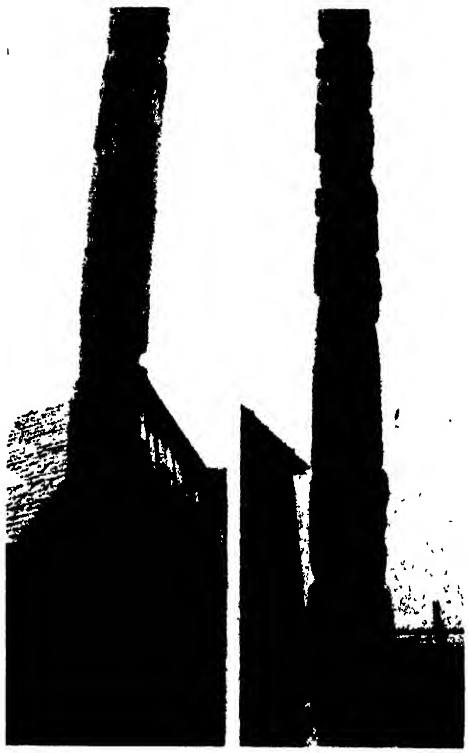
The belief has long been held that the totem poles of the North Pacific Coast are ancient, that they are a typical form of prehistoric art. Yet nothing is farther removed from the truth, if by totem pole we mean, as we should, a detached post consisting of a red cedar tree which was cut, hauled a certain distance—often a long distance—to an Indian village, where it was carved with symbolical figures usually of a heraldic character, and erected in the course of a feast in front of a chief's house to commemorate the passing of his predecessor and his own elevation to office. No totem pole, in so far as we know, ever came otherwise into existence, and this only in the restricted geographical areas, at first, of the Nass River and the Queen Charlotte Islands; next, of the southern Alaskan Coast, the Skeena and neighborhood; and later, of the coast farther south.

These heraldic memorials were derived from three contributing sources: (1) The earlier carved house posts prevailing over a wider area extending southwards to the Fraser River; (2) small graveyard figures of people or animals such as were found all along the coast as far north as Bering and also in adjacent Siberia and Japan; and (3) miniature carvings of stone, ivory and wood which, occasionally recovered on the North Pacific Coast, show that at least some of the stylistic devices of the native carvers were older than the totem poles and presumably went back to Asiatic prototypes.

The Russians in Alaska failed to make any record of any such structure among the Tlingit of Alaska, and the early white navigators along the coast only seldom observed house frontals with carved figures through which there was a round mouth-like entrance. It is only after 1830, more precisely after 1850, that totem poles became a feature of the villages of the Haidas, the Tsimsyan and the southern Tlingit, and after 1890, that they appeared at Alert Bay among the Kwakiutl and among the Nootka on the west side of Vancouver Island. The art reached its apogee between 1860 and 1880, and among outlying tribes like the Gitksan of the upper Skeena, it thrived until after 1900. A few indifferent poles there have been erected in the past ten years, but the custom of thus commemorating the dead as a whole is no longer prevailing, and in most parts the old

totem poles have decayed, fallen down or have been destroyed. Those that were left at the beginning of the present century were a cause of wonder to observers, and some of them were collected for museums or transplanted into public parks. Legends about them grew apace, with the added nimbus of mystery and antiquity, which were due only to the carelessness of the collectors, who neglected



TOTEM POLES
AT KISGAGAS (LOWER BABINE RIVER) AND KISPAYAKS (ON MIDDLE SKEENA) SHOWING THE SHINGLE CREST—THE RIBBED LINES IN THE MIDDLE.

to get the information then easily available.

To emphasize the novelty of totem pole carving and single out the causes which, after 1830, promoted its growth, I will select a few illustrations showing its connection with the fur trade, more particularly with the North West Company and the Hudson's Bay Company.

One of the two upper Gitksan tribes, that of Kisgagas or Sea-Gull near the outlet of the Babine River on the Skeena 225 miles from the sea-coast, was not far removed from Fort St. James, the earliest fur trading post of the North West Company established in 1808 in the northern Rockies. And it seems that the company soon after built a subsidiary post at Bear Lake, under the direction of a Mr. Ross. A Tsetsaut party at that time raided the village of Kisgagas while most of the hunters were away, killed two men with the flint-lock musket in their possession—the first gun seen in the country—and returned home with a female captive, a niece of the head-chief whom they had killed. The young woman was rescued by the white people at Bear Lake and later sent back home. A retaliation party, under her guidance, proceeded to the Tsetsaut country, but decided to visit the white man's fort on the way. Here they had their first opportunity to see the white man and to marvel at his possessions and his strange ways; to them all this was nothing less than a supernatural experience. What impressed them most was the white man's dog, the palisade or fortification of the house, and the broad wagon road—so different from their faint forest trails. All three of these they decided to adopt as their own crests or emblems after they had reached home. Waiget, the head of one family, took upon himself White-Man's Dog or Mr. Ross' Dog (called Masselaws); Malulek, another chief, assumed Palisade as his own; and other participants shared other similar crests. They gave two big feasts in the course of the next two years, to which they invited representatives of other Gitksan tribes as guests. And they exhibited with pride their new acquisitions, which they later carved on their totem poles or built—the palisade in the form of a small fence—around them.

Another family lower down on the upper Skeena, that of Harhu of Kis-

Schallerer

TOTEM POLE IN KETCHIKAN PARK

SUPPOSEDLY REPRESENTING CAPTAIN COOK ON HIS SHIP. THE MODEL PRESUMABLY WAS CAPTAIN VANCOUVER, FIRST WHITE SAILOR SEEN IN THESE PARTS, WHO SURVEYED THE COAST IN 1793.

payaks, likewise acquired the Shingle crest (*Ran'arhgyeek*), obviously from the white man's device of that name, after an ancestor once had proceeded either to the trading post of Bear Lake or Fort St. James. And this Shingle emblem on a Kispayaks totem pole is still seen in the form of parallel lines sloping down on both sides of a central ridge cut deep in the cedar.

Not a few instances of similar origins are noticeable on the totem poles and house frontals of the coast, for instance, the white sailor at the helm of a ship at Bella Coola (a short distance north of Vancouver Island) now preserved at the National Museum of Canada; another sea pilot at the top of a tall pole at Cape Fox, southern Alaska; a sailing ship with a sailor on its deck on a pole recently transplanted to Ketchikan, Alaska, and erroneously stated to represent Captain Cook—it presumably was inspired by Vancouver, who made the first coast map; and the splendid Haida pole now standing in the same park at Ketchikan and showing three Russian priests in church vestments, one above the other, two cherubs with wings out-

KAIGANI-HAIDA TOTEM POLE

(*Left*) OF THE THREE GREEK ORTHODOX PRIESTS (RUSSIAN), THE CHERUB AND THE TWO EAGLES; WITH ANOTHER POLE AND BROKEN SECTIONS OF A POLE, NOW AT KETCHIKAN, ALASKA. THESE HAVE BEEN PAINTED RECENTLY.

spread and two Russian eagles. This pole is from Kasan, a Haida-Kaigani village of Prince of Wales Island; it was carved over sixty years ago and erected, during a potlatch which some old people still remember, for a native family that showed its partiality at the time for the Greek Catholic church of the Russians. Another Kasan pole with scroll fret-work was said by an old Indian woman to have been carved by her uncle, who wanted to represent on it a Greek Catholic church certificate in his own possession.

These emblems were at first foreign to the Indians and have remained, since their assumption, the exclusive property of a few families. The bulk of totem pole figures elsewhere is of a different kind; it symbolizes familiar animals, legends and natural phenomena. The animals most commonly represented are the eagle, raven, frog, finback whale or blackfish, grizzly bear, wolf and thunder bird. Others, less frequently used, are the owl, salmon, woodpecker, beaver, shark, starfish, mountain goat, puma, moon, stars and rainbow. In the last resort these symbols were property marks on the houses and household effects and ceremonial carvings of the owners. They were not pagan gods nor demons, as they are often supposed to be. They are comparable to the stylized figures in our heraldry, yet they usually illustrate myths or tribal traditions. They were never worshipped, and if they were held sacred, it is only because of their implications. They were like tombstones, and indeed some of the same crests were, in the past 50 years, carved out of stone or marble at Port Simpson or Vancouver by white craftsmen for the new graveyards of the Indians.

The legendary origin of many of these emblems was explained in traditional narratives that used to be recited in the winter festivals or potlatches. They are still remembered by the members of the older generation, in spite of the decay of tribal customs. They recount how the ancestors long ago met with tribulations and adventures; how they were harassed or rescued by spirits and monsters; how benevolent spirits appeared in visions and invested their "protégés" with

Pruell

TOTEM POLES AND HOUSES IN THE DESERTED HAIDA VILLAGE OF KASAN

ON PRINCE OF WALES ISLAND, SOUTHERN ALASKA. NOTE FIGURE OF A WHITE MAN WITH A LONG COAT AND TOP HAT ON TOP OF THE POLE TO THE RIGHT.

charms; and how ancient warriors conquered their enemies in warfare. The carved illustrations of these stories served a definite purpose, besides those of commemoration and ownership; they made familiar the legends and recollections of the past to all in tribal life.

Soon after the death of a chief, his prospective heirs appointed his leading nephew to his post. His induction took place in the midst of a large number of invited guests, during elaborate festivals, where liberality was an outstanding feature. The name of the "uncle" passed on to his "nephew" and the erection of a totem pole crowned the event. Groups of related families mustered all the resources available to make the feast memorable, as their standing and influence depended exactly in their resources thus advantageously displayed. If power and wealth were the ruling factors in the life of the North Pacific Coast people, it is obvious that these were modern among them; they issued from repeated contacts with white seamen and traders, from the greed for trade goods and from a keenness and industry inborn among these natives, whose recent origin was Siberian or Mongolian.

The remarkable development of native technique and style in totem pole carving is largely confined to the period subsequent to 1830. It hinged upon European tools, the steel axe, the adze and the curved knife, which were traded off in large numbers to the natives from the days of the early circumnavigators, that is, after 1778. The lack of suitable tools, wealth and leisure in the prehistoric period precluded the elaboration of ambitious structures and displays. The benefits accrued from the fur trade at once stimulated local ambitions; they stirred up jealousies and rivalries, and incited incredible efforts for higher prestige and leadership. The only desire everywhere was to outdo the others in ingenuity, wealth and the display of power. The totem pole came into fashion through the rise of these ambitions. It became the acknowledged way of showing one's own identity in terms of the commemoration of illustrious dead, the decoration of imposing houses and the grand implications of ancient imagery. The size of the pole and the beauty of its figures published abroad the fame of those it represented.

POLE OF NEESTSAWL

AT ANGYADAE ON THE NASS RIVER. CARVED BY OYAI FOR NEESTSAWL, HEAD OF A RAVEN FAMILY. IT STOOD AS A MEMORIAL TO CHIEF ISAWIT. THIS POLE IS NOW AT THE ROYAL EDINBURGH MUSEUM, SCOTLAND.

Feuds over the size of totem poles as a result broke out among the leaders within a Nass River village, after the Hudson's Bay Company had established its trading post on the lower Nass in 1831 and transferred it to Fort Simpson in 1833, and had founded Victoria in 1843.

The Haida poles as we know them in

BEAR AND WOLF TOTEM POLE
OF ANGYADAE ON THE NASS RIVER WHICH WAS ERECTED ABOUT FIFTY YEARS AGO.

our museums are all of the same advanced type and virtually of the same period—1840–1880—and presumably all from the hands of carvers that were contemporaries. Their style was largely the result of miniature argillite carvings made by the ingenious craftsmen for the benefit of an early tourist traffic with the sailors and traders. The poles were from ten to thirty years old when the Haidas became converts to Christianity and in consequence gave up their customs, cut down some of their poles and sold them to white people, about the year 1890 or afterwards. It is a common saying that the fine row of poles in one of their best-known towns had risen from the proceeds of an inglorious type of barter in Victoria. There is no evidence of totem poles among the Haidas antedating 1840 or 1850, though a few earlier and transitional ones had served to introduce the fashion.

If the influence of the white man, his machinery and tools, upon the growth of the native art and totem pole carving of the North Pacific Coast, goes back to the earliest days of the fur trade, it is chiefly after steady contacts had been established by the Hudson's Bay Company that progress attained impressive proportions. One of the earliest references of such influence was given us by the Honorable Judge Howay; namely, that of a seaman named Jefferson who, as early as 1795, lent some machinery to the Haidas, together with sailors to assist, for the erection of a carved pole.

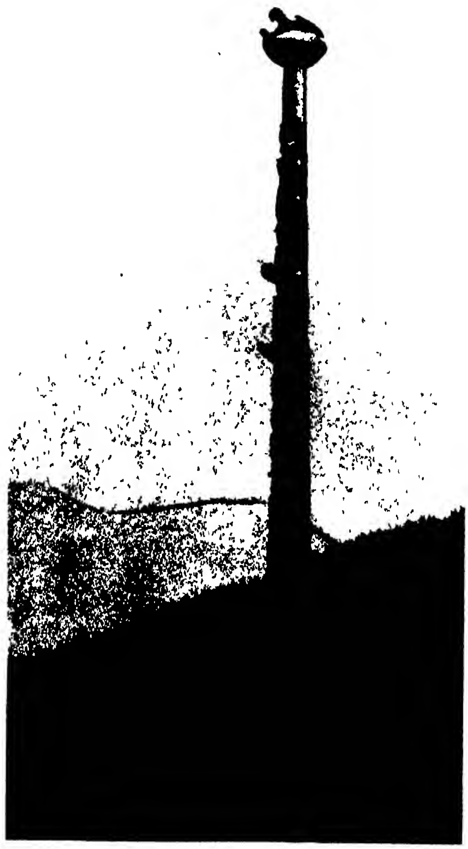
HALIBUT–BEAVER POLE
AT GITIKS ON THE LOWER NASS RIVER. ONLY THE LOWER PART OF THE POLE IS SHOWN.

Some Nass River natives also welcomed outside assistance at an early date; that is, over 100 years ago; and we should not forget that the trench method for starting the raising of a tall pole is identical with that of the South Sea islanders; or that South Sea islanders—Kanakas or Hawaiians or Sandwich islanders—were fairly numerous on the North Pacific Coast, as a result of their early immigration for the service of seamen and the Hudson's Bay Company.

Definite examples of totem poles erected as a result of relations between officers of the Hudson's Bay and the natives are too extensive for full quotation here; yet these include some of the best and tallest samples of the art, in particular on the lower Nass River. I have recently retold elsewhere (*Queen's Quarterly*, Autumn, 1939) the story of how the native wife of Captain McNeil, first of Port Simpson and then of Victoria, had incurred the wrath of her former Indian husband on the lower Nass. As he had publicly ridiculed and shamed her in her absence for her infidelity, she retaliated with the help of her new husband and erected one of the finest poles on the river, that of Bear-Mother and Angyadae, which is now preserved in the Trocadero Museum of Paris. And for variety's sake, other instances may now be briefly given here which belong to the same Angyadae and Geetiks clusters, perhaps the most remarkable of all for their size and quality.

The size of totem poles until about 1860 had had no special significance in itself, except that their carving required more time, and their erection made heavier demands on ingenuity and the many invited helpers in attendance.

Ambitious to excel all other chiefs once the ball was started rolling, Sispegoot, chief of the Blackfish clan on the lower Nass, decided to put up the tallest pole on the Nass, and its name would be Fin-of-the-Blackfish: just the Fin—not the whole Blackfish—to drive home to the other chiefs the sense of their approaching defeat. As if to make matters worse, Sispegoot would not engage Hladerh, his rival of the Wolf clan, as his carver, although Hladerh was entitled to this function by a usage in this tribe; rather he would command the services of Oyai, the canyon totem pole carver who was known to be partly of Kanaka extraction, and whose Grizzly-Bear pole for Mrs. McNeil was such a fine piece of work. So Oyai instead of Hladerh was entrusted by Sispegoot with the enterprise of carving the tallest totem ever seen in the country. This was bound to arouse the wrath of



EAGLE'S NEST POLE
OF THE LOWER NASS, NOW IN THE ZOOLOGICAL GARDEN AT CHARLESBOURG, QUEBEC.

Hladerh, who was already known to be proud and vindictive. But Sispegoot would not be cautious, and he was impatient to take the center of the stage for himself and his followers. He was sure that he could improve on Mrs. McNeil's totem, who at best had become an outsider and spent most of her time away, at Victoria.

However, there is no room here to recount the episodes of this feud about totem poles and prestige, for they are lengthy and varied; they are like an epic. The quarrel, which led to bloodshed, has not yet been forgotten, after a lapse of seventy-five years and the downfall of tribal customs. In a word Hladerh, being the head-chief of the Wolves (Larhkeebu), would not allow the erection of any pole that exceeded his own in height. Sispegoot, the head-chief of the Finback-Whales, could afford to disregard his rival's jealousies. When his new pole was carved, over sixty years ago, the news went out that it would be the tallest in the village. In spite of Hladerh's repeated warnings, Sispegoot issued invitations for its erection; but he was shot and wounded by Hladerh as he passed in front of his house in a canoe. The festival was perforce postponed for a year. Meanwhile Hladerh managed, through a clever plot, to have Sispegoot murdered by one of his own subordinates, thus enforcing his own will. He later compelled another chief of his own phratry, much to his humiliation, to shorten his pole twice after it was erected; and he was effectively checked only when he tried to spread his rule to an upper Nass village abroad.

MEETINGS OF SCIENTIFIC SOCIETIES IN WARTIME

A MEMORANDUM on the holding of meetings of scientific and learned societies in wartime has been prepared within the last few weeks by the Science Committee which is advisory to the National Resources Planning Board, and which is composed of members designated by the National Research Council, the American Council on Education, the American Council of Learned Societies, and the Social Science Research Council. In essence, this memorandum states that in the war period scientific societies have an important part to play in the national effort, and meetings of these societies should be so organized as to be in the best public interest. It suggests, therefore, that each society or association consider its relationship to the war effort, and plan the programs of its meetings so that the most effective contribution will be made. In so far as possible meetings should not be held in or near defense areas, especially the ports and cities of the Atlantic seaboard, and should be scheduled for such days of the week as to avoid week-end travel. Meetings should be distributed among different cities to avoid congestion at any one point or along routes of travel.

The committee emphasized that meetings not closely connected with the war effort should be postponed, and that attendance at all meetings should be confined to those whose presence or participation is believed to be useful. Finally, they pointed out that the above statements are based upon conditions of transportation that exist at the present time, and that changes in these conditions may take place and may necessitate radical changes in plans for meetings. The directors of the Optical Society of America are taking these suggestions into full consideration in laying their plans for future meetings.—*From an Editorial, Journal of the Optical Society of America, October, 1942.*

GEOGRAPHIC ROLE OF THE EVERGLADES IN THE EARLY HISTORY OF FLORIDA

By Professor L. LEMAR STEPHAN

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EXPLORATION and settlement of the Everglades lagged behind that of Florida as a whole. References to the Everglades in journals of early explorers are conspicuous for their scarcity. When settlers succeeded explorers, they chose parts of Florida presenting fewer initial problems than those of a marshland. Men let their imaginations play with the idea of draining and utilizing the "Glades" for a half century after settlement was established in the rest of the state. So not until early in the twentieth century did successful drainage operations make the Everglades appear to many as a new frontier of opportunity, one of the last of many successive frontiers in the United States.

A BARRIER TO EXPLORATION

Early explorers heard rumors of "the place of the big water," but De Soto's map (Fig. 1) does not show any body of water that could be Lake Okeechobee. "When Jacob LeMoyne made his map of Florida (Fig. 2) in 1560, or thereabouts, he placed a large lake in the middle of the peninsula and made this note beside it . . . 'So great is this lake that one bank cannot be seen from the other.' "[1] After this date geographies mentioned the lake. Lake Okeechobee was, nevertheless, regarded by some as legendary as late as the early nineteenth century. Colonel John Lee Williams, who had done considerable traveling in Florida, prepared a map omitting Lake Okeechobee. The very existence of the most conspicuous item in the Everglades landscape, a lake forty miles wide, was open to question three centuries after the discovery of Florida.

Of lands lying southward from Lake Okeechobee even less was known. In 1898 Hugh L. Willoughby wrote in "Across the Everglades, A Canoe Journey:"

> It may seem strange, in our days of Arctic and African exploration, for the general public to learn that in our very midst, as it were, in one of our Atlantic Coast States, we have a tract of land one hundred and thirty miles long and seventy miles wide that is as much unknown to the white man as the heart of Africa. This tract occupies the southern part of the State. It is bounded on the north by Lake Okeechobee, on the east by the pine land about six miles wide facing the Atlantic, on the south by the mangrove swamps facing the Bay of Florida and the Big Cypress Swamp which touches the land of the west coast.

Twenty years later the Everglades had

FIG. 1. MAP DRAWN BY DE SOTO OF THE FLORIDA PENINSULA. HERNANDO DE SOTO WAS THE SPANISH EXPLORER WHO DISCOVERED THE MISSISSIPPI IN 1541.

[1] Charles Ledyard Norton, "A Handbook of Florida," p. 269. New York: Longmans, Green and Company. 1891.

given way to penetration. Then Nevin O. Winter could in retrospect say:

> The Great American Desert, once so feared, the wild solitudes of the Rockies, and the snowy wastes of the Yukon yielded up their innermost secrets before accurate knowledge of the Everglades was extended to the world. Its mystery has been a part of our national inheritance.[2]

The Everglades possessed neither of the two characteristics which encourage exploration of an unknown area. A land easy of access may be visited casually and thus settled. A land offering quick riches provides sufficient incentive to attract the intrepid, regardless of difficulty of access. No "fortune in a day" induced men to penetrate the sawgrass-blocked water routes of this reed-swamp; therefore, for more than three centuries the Everglades raised an obstacle of pure inertia to the movements of man.

[2] Nevin O. Winter, "Florida, The Land of Enchantment," pp. 2–3. Boston: The Page Company. 1918.

A Place of Refuge

"Inaccessible to all except those familiar with their treacherous paths and labyrinthine channels, swamps have always afforded a refuge for individuals and peoples. . . ."[3] No exception to this principle, the Everglades, throughout its history, has sheltered diverse refugees: pirates, runaway slaves, Indians, Confederates and recently various law-

[3] Ellen C. Semple, "Influences of Geographic Environment," p. 371. New York: Henry Holt and Company. 1911.

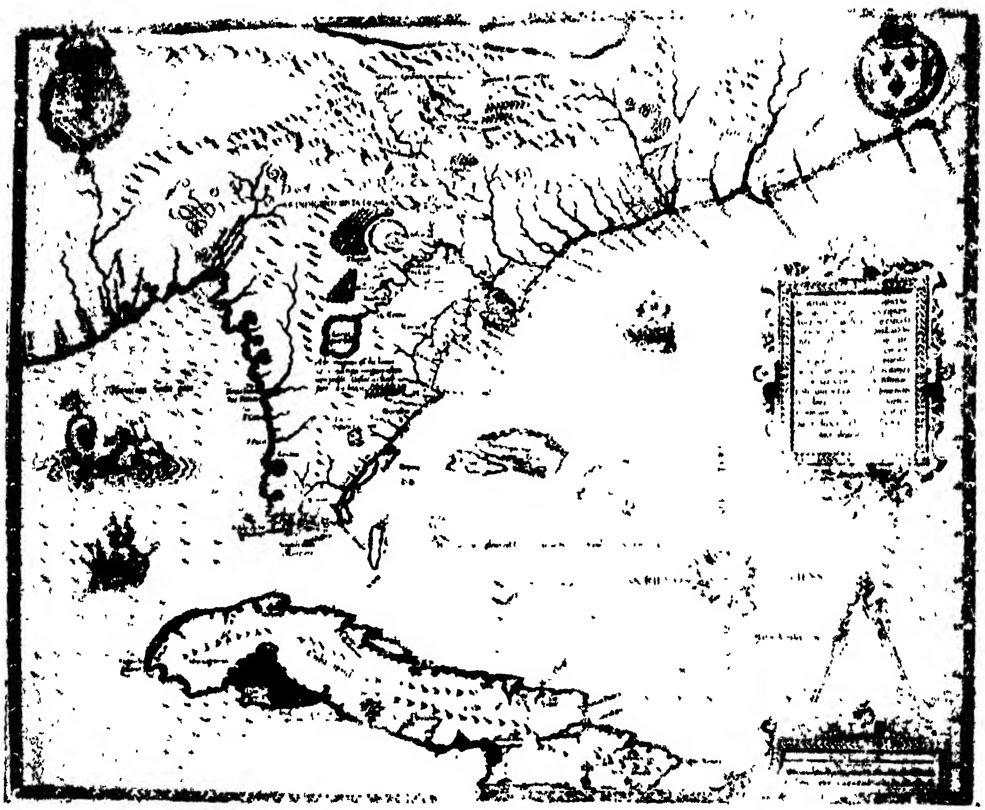


FIG. 2. MAP OF FLORIDA MADE BY JACOB LE MOYNE ABOUT 1560.

U.S.S.C.

MATURE SUGARCANE IN THE EVERGLADES

WHERE ONCE SAWGRASS GREW TO A HEIGHT OF TEN FEET, TO-DAY SEVERAL THOUSAND ACRES ARE IN FIELDS OF TALL SUGARCANE. THIS FIELD OF TYPICAL MATURE SUGARCANE IS ON THE HOLDINGS OF THE UNITED STATES SUGAR CORPORATION.

breakers, including bootleggers. Of these refugees, rumors and legend are many, facts fewer.

Pirates

First in point of time to seek sanctuary in the Everglades were the pirates, who abounded for more than two centuries after the discovery of America. The loot appropriated from the Indians of Central and South America often was re-stolen several times before it reached Europe. ". . . pirates and buccaneers, who ventured along the Florida shores with their ships laden with rich booty, chased here by hostile pursuers . . . , would quickly disappear within the mysterious fastness of the Glades, and were absolutely lost to pursuit. Hence it is, that to this day there are innumerable tales of treasures existing in scuttled boats and of buried wealth in these winding streams."[4] There is no record of discovery of any buried pirate treasure.

[4] Winter, *op. cit.*, p. 296. See also p. vi.

Slaves

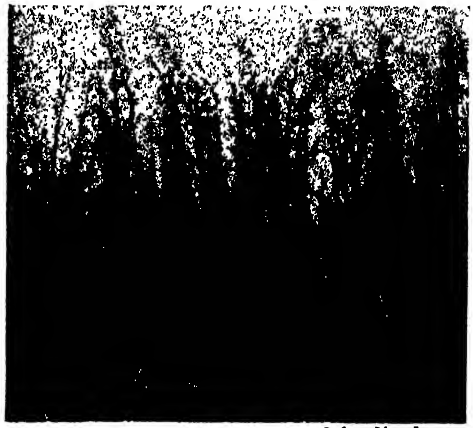
During the first half of the nineteenth century, the prospect of a safe retreat afforded by the Everglades tempted many (usually Floridian) slaves to run away. Some joined the Indians; others banded together with their fellows and became more savage and dreaded than the Indians themselves. The Negroes paid tribute to the Indians in corn. The fact that Indians did harbor slaves, together with the fact that expeditions capturing escaped slaves frequently took slaves owned by Seminoles as well as runaways, caused friction between the whites and the Indians which resulted in the Seminole War of 1835.

Seminole Indians

The Seminole Indians of Florida were a group of "runaways" from the Creeks of Georgia (probably mixing to some extent with the Colusa whom they dispossessed in south Florida, and Carib Indians who early rowed giant canoes

from their West Indian homes to south Florida[5]). The exodus was effected about 1750, after the Creeks had been for a generation allies of the British in their struggle against the Spanish. At the time of the rupture between the colonies and the mother-country, the British succeeded in implanting deep antagonism for Americans in the Seminoles. Attempts to reach an understanding between the United States and the Seminoles were thwarted for a half century by the persistence of mistrust.

The so-called First Seminole War was a direct offshoot of the British-American conflict of 1812–15. Andrew Jackson campaigned briefly in Florida in 1814 and again in 1818. The Second Seminole War resulted, in general, from the continued raids upon Indians for fugitive slaves, and, in particular, from the capture of the wife of Osceola, a prominent Indian leader, as a fugitive slave, although she had merely a trace of Negro blood and was already the mother of Osceola's four children. Relations with the whites had, furthermore, been strained by an attempt, in 1832, forcibly to remove the Indians to Western lands.



John Newhouse

SAWGRASS IN BLOOM

SAWGRASS, A HELIOPHYTE FOUR TO TEN FEET HIGH, DOMINATES THE UNCULTIVATED AREAS OF THE EVERGLADES MARSH OF FLORIDA.

John Newhouse

WILLOW AND ELDER GROWTH

A TRANSITION ZONE ABOUT A MILE WIDE, BETWEEN THE SAWGRASS MARSH AND BETTER-DRAINED CUSTARD APPLE LANDS NEAR THE LAKE, CONSISTED OF DENSELY MATTED WILLOW AND ELDER TREES.

For seven years (1835–42) the war dragged on, costing the United States about $30,000,000 and many lives. The Indians retreated to the Everglades, where they were virtually secure from attack. "Many short scouting expeditions were made in the northern part of the Everglades, but when the troops got away from their base of supplies, the travel being slow and uncertain, they experienced terrible hunger and fatigue and were glad to turn to the coast."[6] Though a few of the Indian camping places were found and their crops destroyed, only once was the elusive Seminole defeated in battle. Finally,

> On February 18, 1842, Colonel Worth reported that there were but three hundred Indians, including women and children, left in Florida. He said that it was impossible to secure these by force, and he, therefore, proposed that the number of troops in the territory be reduced. . . .[7]

[5] Harriet G. Blackwell, "Our Most Beautiful Land Shell," *Natural History*, April, 1940, Vol. XLV, p. 217.

[6] Hugh L. Willoughby, "Across the Everglades, A Canoe Journey," p. 19. Philadelphia: J. B. Lippincott Company. 1898.

[7] Caroline Mays Brevard, "A History of Florida from the Treaty of 1763 to Our Own Times," Vol. 1, pp. 162–163. Ed. James Alexander Robertson. 2 vols. Deland, Florida: The Florida Historical Society. 1924.

John Newhouse

CLEARING A ROADWAY

RIMMING THE SOUTH SHORE OF LAKE OKEECHOBEE WAS A BELT OF CUSTARD APPLE TREES AS MUCH AS A MILE AND A HALF DEEP.

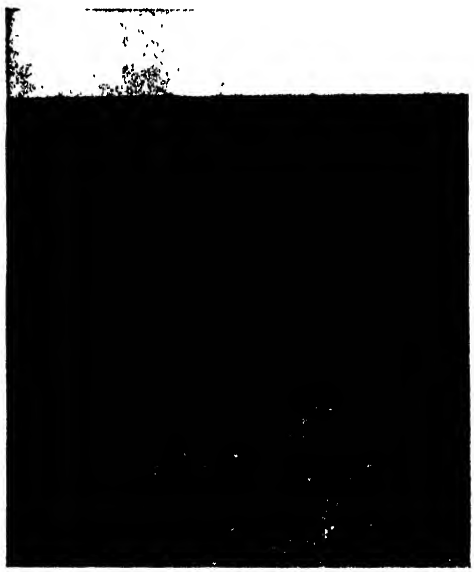
He reached a personal understanding with the Seminoles that so long as they let the whites alone, they should not be disturbed. This compact has been better kept by the Indians than by the whites.

Prior to the cessation of fighting, about five hundred Indians and their Negroes were persuaded to emigrate to Oklahoma. Later it was decided that the Indians remaining in south Florida should be granted a reservation. The lands assigned to the Indians extended from the mouth of the Peace Creek to the fork of its southern branch, thence to the head of Lake Istokpoga, thence down the Kissimmee to Lake Okeechobee, through the Everglades to the Shark River, thence along the coast to the starting point.

After peace was established, in 1842, federal troops proceeded to explore southern Florida and to make roads. In 1852 a small steamboat and nine metallic boats were provided for use on Lake Okeechobee and elsewhere in the vicinity.

In 1855 came the "incident" inevitable when white men seek to open up an Indian domain for civilization. An exploring party under Lieutenant Hartsoff destroyed banana trees and shot pumpkins in the garden of Chief Billy Bowlegs. The next day Hartsoff's party was attacked and soon afterwards raids were made on the homes of white settlers near the coast. State troops were called out and served nearly three years before order was restored.

The superintendent of the Western Seminoles, with two assistants and forty-six Indians, arrived in Florida January, 1858, and persuaded Billy Bowlegs and his followers to emigrate. Pecuniary inducements were offered to the chief and his people. . . . May 4 was the day fixed for the emigration. On that day the Indians came in from their homes in the Glades, slowly and quietly made their way to the wharf, and silently took their places on the steamer that was to bear them from the home they loved. One hundred and twenty-three had come voluntarily with their Chief; forty-one had been captured. A remnant of the tribe, about a hundred, it was said, remained hidden in the Everglades. They were so few that neither state nor national government made further efforts to remove them.[8]



Everglades Experiment Station

ROW UPON ROW OF CELERY PLANTS

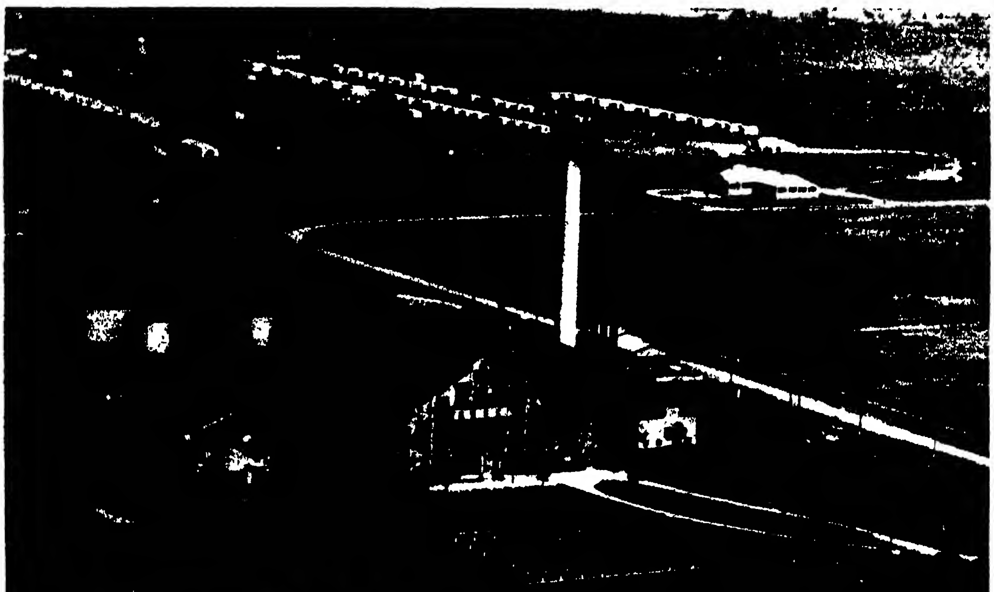
PRODUCTION OF WINTER VEGETABLES FOR NORTHERN MARKETS VIES IN IMPORTANCE WITH THE CULTIVATION OF CANE IN MODERN EVERGLADES ECONOMY. NUMEROUS PACKING HOUSES ARE AN ADJUNCT TO THIS FARMING AREA.

[8] Federal Writers' Project of the Works Progress Administration for the State of Florida, "Florida, A Guide to the Southernmost State," p. 47. New York: Oxford University Press. 1939.

Everglades Experiment Station

A CYPRESS HAMMOCK EAST OF LAKE OKEECHOBEE

HERE THE GRASSLAND IS DOTTED WITH OCCASIONAL "CYPRESS DOMES." IN APRIL, 1933, THESE FEW BALD CYPRESSES STOOD AMIDST CULTIVATED FIELDS.



U.S.S.C.

SUGAR HOUSE AT CLEWISTON ON LAKE OKEECHOBEE

ON THE SOUTHWEST SHORE OF THE LAKE THE UNITED STATES SUGAR CORPORATION HAS A LARGE SUGAR HOUSE WHICH LOOMS UP CONSPICUOUSLY ON THE LOW HORIZON. IN THE BACKGROUND ARE THE CLEAN, WELL-SPACED HOUSES OF THE WORKERS.

Technically, peace was not concluded with those who remained until the signing in 1934 of a truce and a subsequent treaty.

The Seminoles remaining in Florida lived to themselves, quietly hunting, fishing and gathering turtle eggs.

As late as 1872 there were rumors that an outbreak might take place at any time and consequently, an agent appointed by the commissioner of Indian Affairs visited them in the Everglades to report upon the state of affairs among them. He found them altogether peaceable and living to themselves. Three years later the Commissioner urged that public lands should be secured for their occupation, lest upon them should fall the fate of the Mission Indians of California. But for some time nothing was done.[9]

An Act of Congress had in 1850 granted the swamp lands of the southern portion to the State of Florida. Finally, in 1891, certain lands were set aside for the Seminoles.

Draining of the Everglades was well under way within two decades after the allotment of a reservation for the Indians. Lowering of the water table produced a marked decrease in the supply of game on which the Seminole depended. There appeared to be, moreover, danger that the white man might covet and possess himself of all Indian lands. This latter fear has proved unfounded. In addition to 100,000 acres set aside for them by the State, the Seminoles in Florida own about 26,000 acres of land, part of it purchased for them by the federal government, and the rest set aside for them by executive order.

At present employment is found for Indians desiring to live near settlements on government-directed reservations. Cattle raising is the chief occupation. (In 1938 the reservation at Brighton had around 1,300 head of cattle.)

Everglades Experiment Station

STEAM SHOVEL AT WORK ON THE CONSTRUCTION OF A LAKE LEVEE

ORIGINALLY LAKE OKEECHOBEE PERIODICALLY SPILLED OVER INTO THE BASIN-SHAPED EVERGLADES. TO-DAY THE LAKE, WHICH HAS BEEN LOWERED BY A SERIES OF CANALS, IS FURTHER RESTRAINED BY A LARGE DIKE AROUND ITS SOUTHERN HALF.

Since the closing of the Indian wars, Seminole Indians in Florida have increased from nearly 100 to approximately 600. There are four separate bands or tribes (the Big Cypress, the Miami, the Okeechobees and the Tallahassees), but they are all on most friendly terms with one another.

No longer does the Seminole seek to elude the white man; now he desires to attract him.

In one notable instance, where the United States Army and a hundred years of persuasion failed, a highway has succeeded. The Seminole Indians surrendered to the Tamiami Trail. From the Everglades the remnant of this race emerged, soon after the trail was built, to set up their palm-thatched villages along the road and

[9] Brevard, *op. cit.*, Vol. 11, p. 199.

to hoist tribal flags as a lure to passing motorists. Like their white brethren, they sell articles of handicraft and for a nominal fee will pose for photographs.[10]

Thus, as the swampy character of the lands disappeared, the Everglades ceased to be a "place of refuge" for the Indians.

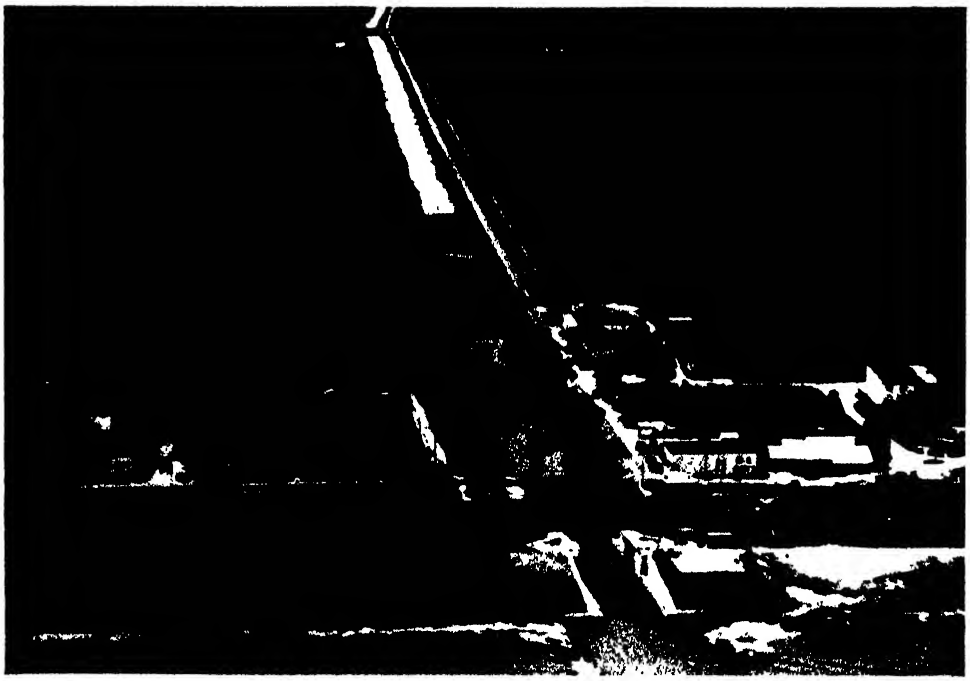
Confederates

The connection between the Everglades and the Civil War has not been widely publicized. Although several of the Confederate cabinet members fled toward Florida at the close of the war, none sought refuge within the "Glades"; rather, it was the deserter and fugitive who sought a safe retreat there.[11] The marsh concealed both deserters and refugees.

[10] Federal Writers' Project, "Florida," p. 5.
[11] Norton, *op. cit.*, p. 269.

Outlaws

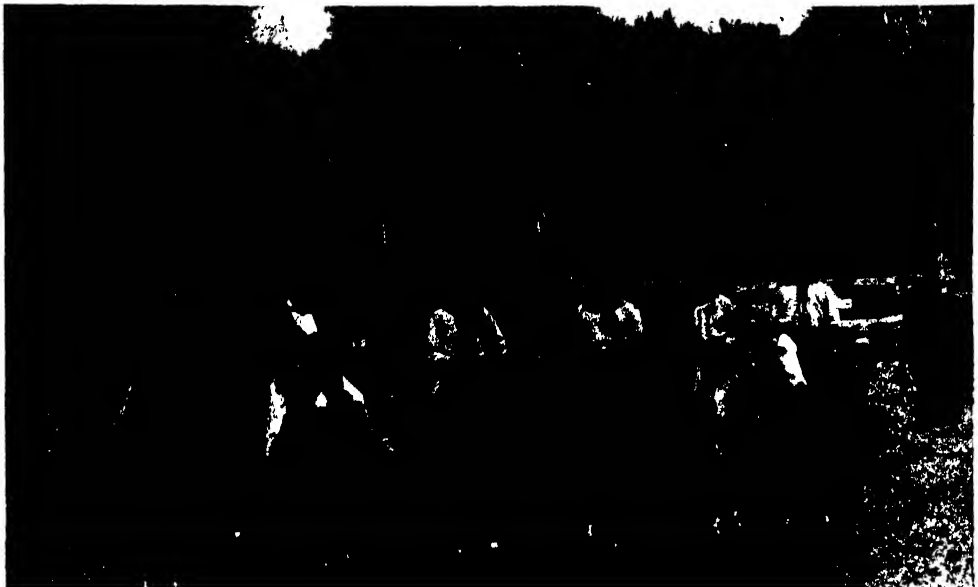
So long as transportation within the Everglades was poor, it continued to be a hiding place for individuals who sought safety and sanctuary. Whether they were fugitives from justice or injustice, moonshiners or murderers, criminals of the chain gang or mere honest smugglers, the Everglades harbored them and concealed them. Most notorious of criminals there were members of John Ashley's gang, who from 1910 to 1924 robbed banks and hi-jacked liquor trucks, secure from capture because they were "swallowed up" by the tract of marsh after each crime. The whole district breathed easier after Ashley and three of his followers were killed in gun battle at the Sebastian River bridge, in November, 1924.



U.S.S.C.

LOCK IN THE WEST PALM BEACH CANAL

CANALS SUCH AS THIS TRANSFORMED THE EVERGLADES FROM AN ALMOST IMPENETRABLE MARSHLAND TO A PRODUCTIVE FARMING REGION. NOTE THE LEVEE, LOCK AND VILLAGE OF LINEAR PATTERN IN THE FOREGROUND AND SUGAR CAMP, PUMP HOUSE AND CANE FIELDS IN THE BACKGROUND, CRISSCROSSED WITH LATERAL CANALS.



F. C. Scott

FIVE SEMINOLE INDIAN COWBOYS AND A WHITE MAN

That the flat terrain of the "Glades" can easily be used for airplane landing fields was turned to commercial advantage at one time.

During the "dry" period of national prohibition, the Everglades proved a veritable godsend to a small army of gentlemen engaged in the somewhat risky but highly remunerative game of rum-running. Swift airplanes, laden to the limit with Bacardi, whiskey, gin, and other wet goods from Bimini, Grand Bahama, Nassau, or even Cuba, would come roaring into the Everglades, and, dropping down to secret landing fields, would be met by motor cars and trucks with little fear of being caught by federal or state officers.[12]

The coming of paved highways has necessarily exposed would-be fugitives in the "Glades" to danger of capture. As shipment of its farm produce has become easier, the value of the Everglades as a place of retreat has declined.

Period of Exploration and Exploitation

An anomalous region—neither truly land nor truly water—the Everglades touched the imagination of many who viewed it. They envisioned it not as a vast barrier and waste land, but yielding to man its richness of soil, the surface water having been removed in some way. In the nineteenth century the marsh was more adequately explored and exploitation was begun.

The first white man to visit the Everglades may well be forgotten, for he came unwillingly and left virtually no record of his stay. Early in the sixteenth century this Spaniard, Escalente de Fontenado, was shipwrecked in the Strait of Florida and carried into captivity by the Cacique tribe of Indians. Although he was released after seventeen years, little was learned from his scanty accounts of the character of this prairie.

The "Glades" seem to have been given slight attention until after Florida came into the possession of the United States. Fifteen years later, in 1834, an act was passed "for the purpose of facilitating the drainage of lands." During the territorial period, indeed, was the first discussion heard of the drainage of the

[12] A. Hyatt Verrill, "Romantic and Historic Florida," p. 114. New York: Dodd, Mead and Company. 1936.

FIG. 3. U. S. WAR DEPARTMENT MAP OF FLORIDA MADE IN 1856

THIS MILITARY MAP OF FLORIDA SOUTH OF TAMPA BAY, IN ALL ITS MINUTE DETAIL, WAS ENGRAVED ON STONE. INDICATED BY SEPARATE LITTLE SIGNS ARE SUCH ITEMS AS PINE, OAK, CYPRESS AND PALMETTO TREES; DWELLING HOUSES; OCCUPIED AND UNOCCUPIED FORTS; AND BATTLEGROUNDS.

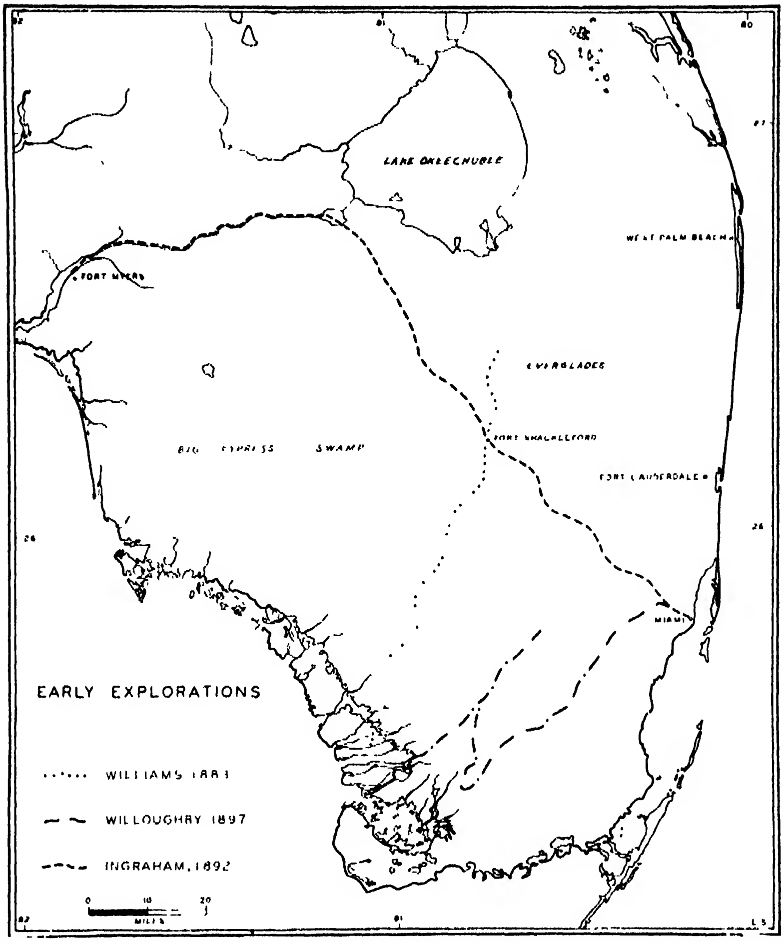


FIG. 4. MAP SHOWING EARLY JOURNEYS THROUGH THE EVERGLADES

Everglades. Not until many years later, however, was action taken in this direction.

It was the war with the Seminoles that brought the Everglades into prominence. Three effects may be noted. First, there was some public discussion of the question of draining these lands, even though the subject did not evoke great interest. Second, there were expeditions bent on exploring the region, under the leadership of Marchand and Roger in 1842, and of Lieutenant Martin in 1847. In 1855 Captain Dawson reconnaissanced with an Indian guide and a considerable party. And, finally, the War Department published in 1856 a map of southern Florida, remarkable in detail and accuracy (Fig. 3).

Once the Civil conflict and its immediate repercussions had passed, the Everglades again engaged the attentions of adventurous souls. In 1881 drainage was begun in the northwest quadrant of the "Glades" by the Diston Company. From 1883 to 1897, explorers boldly traversed the hitherto inaccessible portions (Fig. 4). "The first attempt to make a lengthened journey through any part of the Everglades in the interest of geographical research was made by A. P. Williams in 1883, the expense of which

F. C. Scott

SEMINOLE CATTLE ON THE GLADES COUNTY INDIAN RESERVATION

CATTLE RAISING IS INCREASING ON PLANTED PASTURES IN THE UPPER GLADES.

was covered by a southern newspaper. This was called the '*Times Democrat* Expedition,' (*New Orleans Times Democrat*). . . . "I fear, however," writes Willoughby in 1898, "that accurate survey must have been abandoned at a very early stage, as I can find no map with any stations, the line being devoid of points from start to finish, and simply gives a general direction from the Harney River to Lake Okeechobee."[13] Later a party of twenty-two, led by J. E. Ingraham with J. W. Newman as engineer, traveled from Fort Myers to Fort Shackelford and thence to Miami. The report of this expedition led to extension of the Flagler railroad south along the east coast of Florida, reaching the present site of Miami in 1895. In his journey of 1897 Lieutenant Hugh L. Willoughby crossed the "Glades" in the latitude of Miami.

At the opening of the nineteenth century, the Everglades was an unexplored marshland impeding exploitation, useful only as a place of refuge. At the close of the century, enough was known of its nature that successful drainage operations could immediately be enterprised.

[13] Willoughby, *op. cit.*, p. 21.

STRUCTURE OF THE WOOL FIBER AS REVEALED BY THE MICROSCOPE

By Dr. CHARLES W. HOCK

RESEARCH ASSOCIATE OF THE TEXTILE FOUNDATION, NATIONAL BUREAU OF STANDARDS

SINCE antiquity the hair-like covering of the sheep has been spun and made into cloth. Although all animal hairs are similar, the wool of the sheep combines to an unusually high degree those properties which make a material suitable for the manufacture of textiles. During 1941 the amount of wool consumed in the United States reached an all-time high of 652,200,000 pounds. This poundage represents an enormous number of individual fibers. It is, however, upon the structure of the single fiber that the useful properties of the finished fabric are ultimately dependent. What, then, is the structure of the wool fiber?

To the naked eye wool fibers look like simple filaments, not greatly unlike cotton, silk or rayon. Through the eyes of the microscope, however, the minute architecture of the fibers is revealed, and under these conditions of examination the wool fiber shows many characteristics whereby it can be distinguished from other fibers which it resembles superficially.

All animal hairs, including those of man, are similar to each other with respect to their origin and growth and to their physical and chemical properties. They arise as appendages of the epidermis, or outermost layer of the skin, and

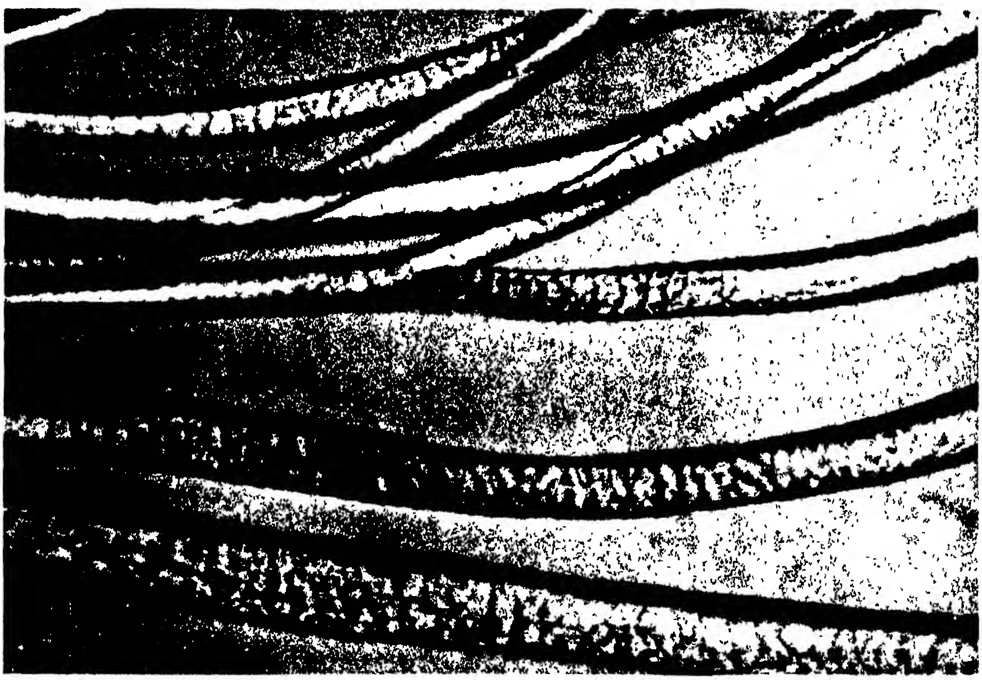


FIG. 1. SEVERAL WOOL FIBERS

THE OUTLINE OF THE SCALES IS FAINTLY VISIBLE. MAGNIFICATION × 150.

show resemblances to related structures such as nails, horns and feathers. Each fiber consists of a root and a shaft. The root is situated in a pit below the surface of the skin and is made up of cells which are all more or less alike. The fiber increases in length by the proliferation of new cells in the root and the subsequent emergence of these cells into the shaft. The shaft is composed of dead cellular units which are usually arranged in three layers—an outer layer of scales, a middle region called the cortex and a central core or medulla. The relative thickness of each of these layers varies considerably in different fibers. In the best grades of wool the medulla is absent or very small.

In the microscopic examination of wool the fibers are usually mounted in a liquid, frequently water, as this renders their characteristics more distinct. Even under low magnification the scales on the surface of the fiber can be discerned (Fig. 1). Their size, shape and arrangement differ in various types of wool and are often sufficiently characteristic to permit identification of the fiber. Although much can be learned about wool fibers by examining them in an aqueous mount, this method yields little information about the detailed structure of their constituent cells. In order to study the minute structure of the various types of cells, the fibers must be treated in a way that makes a more detailed microscopic examination possible. For this purpose thin cross (Fig. 2) and longitudinal sections can be employed to good advantage, but the liberation of single cells from the fibers is even more satisfactory. Chemical reagents, enzymes and microorganisms can be used as tools to break down wool fibers into their constituent cells. Fig. 3 (A, B and C) shows, for example, fibers which have been attacked by enzymes, with a resultant breakdown. Although the scales are relatively resistant to this action, most of the cortical cells have been separated from each other and removed from the fiber.

FIG. 2. FIBER CROSS SECTION
THE THIN SCALE LAYER OF THE WOOL FIBER, AND THE CORTICAL CELLS WITH THEIR NUCLEI ARE VISIBLE, BUT NO MEDULLA IS PRESENT. MAGNIFICATION × 1500.

The cortical layer, to which the strength and elasticity of wool are mainly attributed, forms the largest part of most wool fibers. This layer is made up of cells which are spindle-shaped and which vary in size depending on the sample of wool. About 300 of them placed end to end would extend one inch. Placed side by side it would take about 10 times that many to cover the same space. Near the center of each cell a structure resembling a nucleus can be detected. The nucleus is granular, whereas the rest of the cell has a fibrillate appearance (Fig. 4, A). The two regions differ also in their staining properties and in their appearance in the polarizing microscope. When examined with the latter instrument the nucleus appears as a dark, elongated area in a bright cell (Fig. 4, B). This clearly indicates differences even within a single cell. The fibrillate appearance of the cortical cells is due to the presence of fine, thread-like structures which lie parallel to each other and which can be separated by the fine glass needles of a micromanipulator. Figure 5 (A, B and C) shows a single cortical cell being dis-

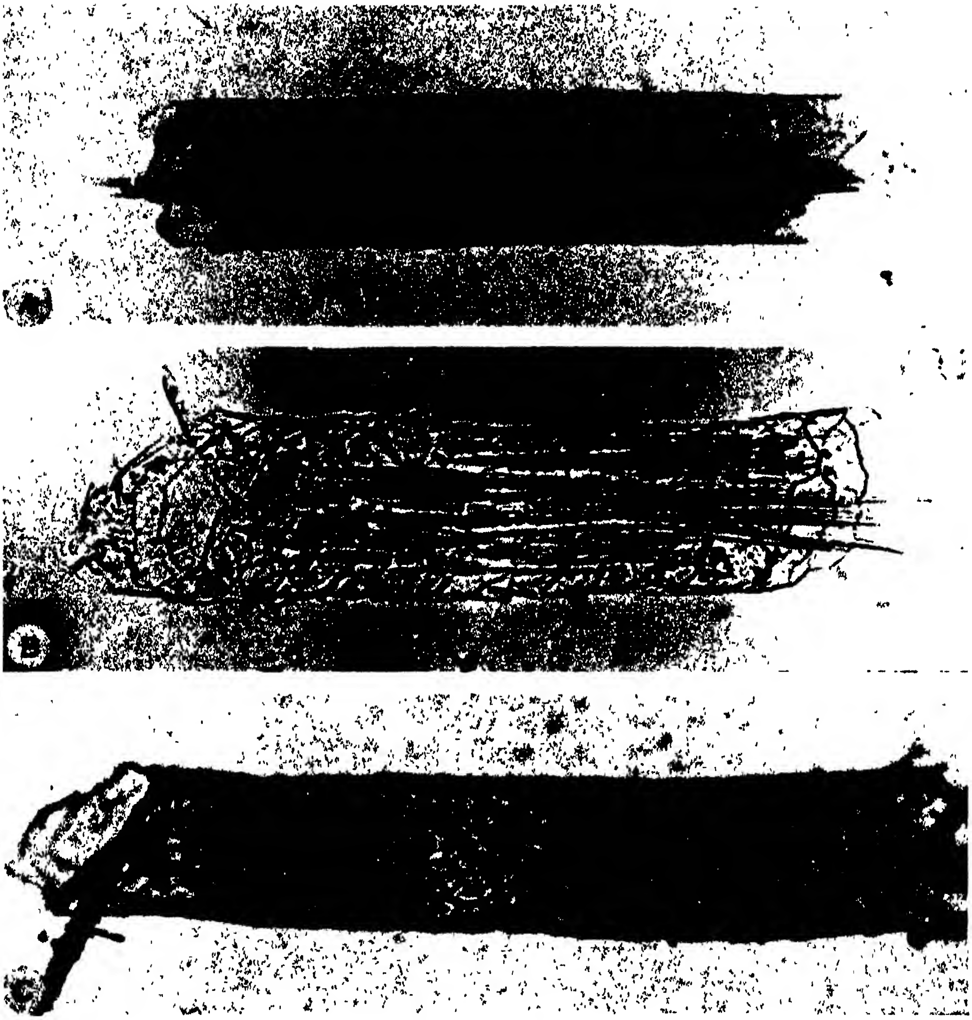


FIG. 3. WOOL FIBERS ATTACKED BY ENZYMES

IN *A* AND *B* SOME OF THE CORTICAL CELLS REMAIN IN THE FIBER, BUT IN *C* THEY HAVE BEEN REMOVED ENTIRELY, LEAVING ONLY A HOLLOW TUBE OF SCALES. MAGNIFICATION × 425.

sected into its constituent fibrils. In this connection it is interesting to note that no matter how far natural textile fibers like cotton, flax, silk and wool, are subdivided they always have a fibrous structure. Recent studies show that even at the high magnifications obtainable with the electron microscope, the fibrous nature of these fibers is still evident.

The scales form the surface of the fiber and serve as a protective armor. As many as several thousand of these thin irregular plates cover every inch of fiber surface and present a multitude of beautiful forms. The scales overlap each other in a manner comparable to the arrangement of shingles on a roof or scales on a fish (Fig. 6). They show little internal organization such as exhibited by the cortical cells and with fine needles it is not possible to dissect them into fibrils. Examinations with the

found differences between these two regions of the fiber. Some of these differences are revealed upon examining fibers which have been pulled from the back of a sheep so as to have the roots attached to the shaft. The root is found to be soft and easily crushed, whereas the shaft is tough and horny. A micro-

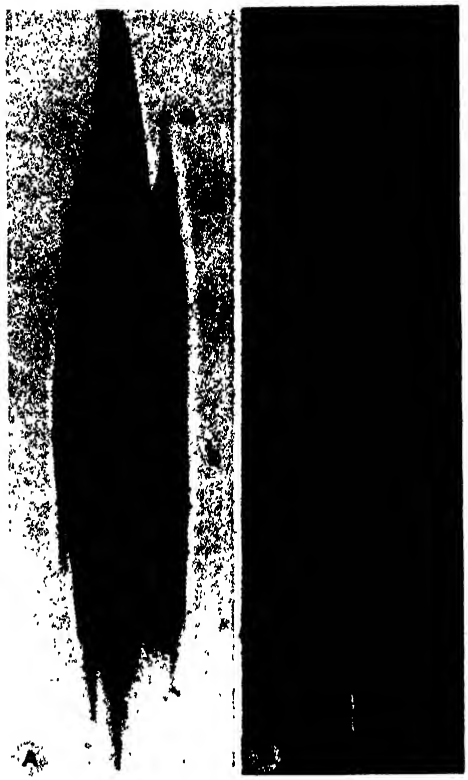


FIG. 4. SINGLE CORTICAL CELLS
A SHOWS THE GRANULAR NUCLEUS AND THE FIBRILLATE APPEARANCE OF THE REST OF THE CELL. IN *B*, THE DIFFERENCES IN ORIENTATION ARE DETECTABLE WITH THE POLARIZING MICROSCOPE. MAGNIFICATION × 1275.

polarizing microscope indicate, furthermore, that the material in the scales is not highly oriented.

The central core or medulla, when present, consists of rather large cells which contribute little to the desired mechanical properties of the fibers. By careful breeding of the sheep, wool has been obtained in which the medulla is absent, the fiber in such cases consisting of only a cortex surrounded by a layer of scales. Pigment, when present, is distributed in the medulla and cortex, in the form of small particles.

Since the cells of the root are alive and growing, whereas the cells of the shaft are dead, it is not surprising to find pro-

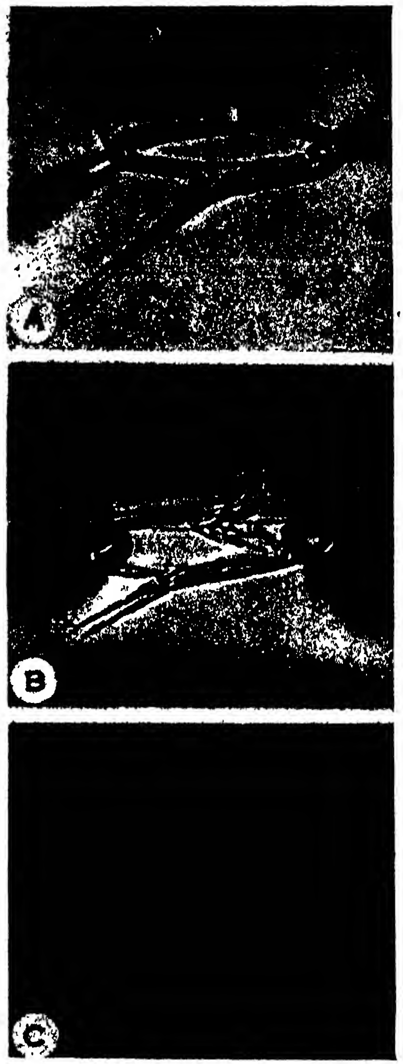


FIG. 5. DISSECTION OF CELLS
THREE CORTICAL CELLS BEING DISSECTED WITH MICRO NEEDLES TO SHOW THEIR FIBRILLATE STRUCTURE. MAGNIFICATION × 575.

scopic examination shows that all the cells of the root are more or less similar. They are round in shape and have a granular appearance. On the other hand, the cells in the shaft are elongated, fibrous in appearance and are differentiated into distinct layers, as previously described. Observations with the polarizing microscope show that the material in the shaft, unlike the material in the root, possesses a relatively high degree of orientation.

Besides differences in cellular structure, a comparison of the root and shaft also reveals differences in chemical structure. Thus, for example, when certain microchemical color tests are applied, the two regions frequently differ in their reactions. The nuclei in the cells of the root react positively to tests for nucleic acid, whereas the nuclei in the cells of the shaft do not produce the red color indicative of a positive test (Fig. 7). Similarly, when the fibers are tested for chemical groups called disulfides, only the shaft gives a positive test. These observations show that as the cells of the root mature and pass out into the shaft a number of physical and chemical changes take place simultaneously. A knowledge of these changes and especially of their relation to the structure and properties of the fiber is essential for the best utilization of the fibers during manufacture.[1]

FIG. 6. WOOL SCALES
A GROUP OF SCALES AFTER RELEASE FROM THE FIBER. MAGNIFICATION × 1475.

FIG. 7. ROOT AND SHAFT
PART OF A FIBER WITH ROOT ATTACHED, SHOWING DIFFERENCES IN STAINING PROPERTIES OF THE TWO REGIONS. MAGNIFICATION × 120.

[1] This paper is based on "Microscopic Structure of the Wool Fiber," by Charles W. Hock, Robert C. Ramsay and Milton Harris, which appeared in the *Journal of Research of the National Bureau of Standards*, 27: 181–190, Research Paper 1412, the *American Dyestuff Reporter*, 30: 449–456, and *Textile Research*, 11: 415–428, August, 1941.

STRANGE STORIES OF FISH

By Dr. E. W. GUDGER
HONORARY ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

It is well known that in certain parts of the world, particularly in Africa, certain birds accompany large herds of grazing mammals, to feed on the grasshoppers and other insects that are stirred up by the forward-moving beasts. This is a curious and interesting feeding relationship. But in this same Dark Continent there is a closer, more curious and more interesting one between two species of small birds and the rhinoceroses. These little birds light on and run about over the backs of their friends and hosts, seeking for the ticks found in and around the folds of their skins. Thus they free their hosts of these annoying blood-sucking parasites and get their own food at the same time. And in return for their free meals, the "rhinoceros birds," on the approach of danger, rise up and with loud chatterings warn their hosts. This relationship is well established and well known, but that fishes should relieve cattle of annoying flies and men of ticks is surely something new under the sun.

Insects are one of the chief foods for a large category of fishes, but for the most part these insects are the forms that either live in or near the water or spend their early lives therein. In short, when we speak of insects as food of fishes, one means those forms that may properly be designated "water insects." But, on the other hand, this short article has to do with the most unusual and extraordinary kind of insect food that any fishes ever ate. These fish-eaten insects are dry, very dry, land forms, which on

A CHUB PICKING BLOOD-SUCKING FLIES FROM A COW

THE LITTLE CHUBS HAVE BEEN OBSERVED IN THE NIOBRARA RIVER IN KANSAS TO JUMP NEARLY A FOOT OUT OF THE WATER TO REACH FLIES ON THE SIDES OF CATTLE.

vegetation lie in wait for and attach themselves, as bloodsuckers, to men and animals. This parasitism has long been known, but the manner in which the fishes get their food from these hosts has (so far as I know) been described by but three writers.

The tropical explorer, Ivan T. Sanderson, in his delightful book, "Living Treasure" (New York, 1941, pp. 89 and 90), tells a story of how little fishes in a stream in Honduras relieved himself and his companions of a multitude of viciously infesting ticks. The story is interesting and we will let him tell it in his own words:

> It has been suggested that Pandora opened her blasted little box on the upper Orinoco River in South America. If this is true, she must have been a British Honduranean and have collectel her pests in her homeland, for the place is the very epicentre of all biting six- and eight-legged pests. Among these are small ticks, known locally as warri-ticks, which come in two sizes: adults at one and a half pinheads and by the hundreds, and immature at a pinpoint and by the thousands. These abominations lie in solid bunches on stalks, bits of grass, and so forth, awaiting the passage of some greater beast. If you touch such a congregation, they all flood onto you in what is literally the flicker of an eyelid of time. Then they spread out like a *Panzer* column and infest the whole of you, and there is only one sure cure. You undress, leave your clothes, jump into the nearest billum pool, and then try to lie quiet. The little billums get to work, and in no time divest you of every tick. The operation drives you nearly crazy, but it is better than the torture inflicted by the ticks should they get at your skin.

It is a matter of much regret that Sanderson did not get a photograph or at any rate make a sketch of this most interesting incident. But he does add this further account of the activities of these helpful little fishes, which he thought were cichlids but which were not collected and positively identified:

> Now I can't find out whether this is a purely British Honduranean word for a special kind of fribble, but these billums are common enough in other tropical countries. In fact we have often encountered them, though I must admit that never before had they quite such an individuality. "Billums" is a general term in British Honduras for little fish in fresh water. Now little fish infest most streams in the tropics, and in many they come and tickle you if you lie quiet, but in British Honduras their activities are so single-minded and so determined that they have gained for themselves this special title. As soon as you enter the water, they dash at you and start tickling. They nibble gently at your toes and your elbows, they pull the hairs on your legs in a playful manner, and they float around in swarms with their watchful little eyes upon your every movement. You can't drive them off and yet you can't catch them even if you tempt them with bread crumbs in a net. They are frightfully cunning. They are most remarkable little people.

This will seem preposterous to some of my readers, but are they right? For twenty years, I have carried in a poor memory the faint recollection of two corroborating accounts. Let us look them up and consider them.

One relates how small fishes rid cattle of their infesting insect parasites. This is contained in a short article—"The Chub and the Texas Horn Fly" by Roy L. Moodie in the *American Naturalist* for March, 1909. The previous summer (1908), while on a fossil-hunting trip in country drained by the upper reaches of the Niobrara River in Kansas, his attention was called to the great numbers of horn fly (*Haematobia irritans*) on the stock in the neighborhood. This fly is so named because it has the habit of clustering around the bases of the horns of cattle to suck their blood. It is a great pest. However, since the cattle under observation were for the most part "muleys," the flies would settle all over their backs and sides. The little fish in this case is scientifically known as *Semotilus atromaculatus*. Here is how the cattle obtained water and at the same time got themselves freed of their pests:

> The cattle would almost always enter the stream at the shallow part of the ford and gradually wade up stream, drinking as they went, until they came to the deep place near the fence where the water reached well up to their bellies. The chubs seemed to be unusually num-

erous at the ford, and we often wondered at the great numbers of the little fishes which we could see in schools in the clear water. Their presence was soon explained. As soon as the cattle entered the stream at the shallow place in the ford the chubs would come out from their cool and shady retreats under the grasses along the sides of the bank and hasten to meet the cattle at the shallows. Often we saw as many as a dozen or more chubs following a single cow. As soon as the water came near the bellies of the animals the chubs would leap out of the water and catch the horn flies from the sides of the cattle. Often we saw them leap as much as half their length out of the water to secure a fly which was high up on the animal's sides. These observations were made on several consecutive days, and on the last day but one I was so fortunate as to secure a photograph of a chub in the act of catching a fly from the side of a cow and the photograph is published herewith.

That the fishes actually learned that the dark spots on the sides of the cattle made good food, there can be no doubt. Just how they first learned it we may not know. The chubs had further learned that the coming of the cattle meant food for them, hence they would meet the cattle in the shallows and follow them to deeper water. The act of these fishes leaping to secure flies from the sides of cattle is so unusual that it is deemed worthy of notice and it is hoped that the incident may be of service to those interested in animal behavior.

Dr. Moodie says further: "Mr. Albert Thomson called my attention to the actions of the fishes and we together made the . . . observations." The Mr. Thomson referred to is our Albert Thomson, head of the laboratory of paleontology in the American Museum. He tells me that he repeatedly saw the chubs picking the flies from the cattle, and that they would sometimes jump nearly a foot out of water to get a fly.

The photograph from which the cut was made was a poor one. The resulting poor cut was printed on soft paper, and the impression during thirty-three years has faded. Dr. Moodie died some years ago and the negative has disappeared. It was necessary to photograph the figure on the printed page and then partially to redraw it. This, skilfully done under my supervision, has been chiefly the painting in of a background and the sharpening of outlines—things that should have been done before the photograph was sent to the engraver. The essential features of cow and fish are as they were in the original. The amended photograph, as reproduced herein, along with the printed figure of 1909 have been shown to Mr. Thomson, and he states that this new illustration accurately portrays what he saw take place.

But what about the other reference to fishes doing a similar service to men? This is contained in the *American Naturalist* for January, 1872. On page 48 is the following account credited to "Exchange." It is greatly to be regretted that more is not known of the source:

Fishes as Surgeons.—In walking through the long dank grass of the forest, an almost imperceptible, minute sort of ticks attached themselves to the ends of our trousers, and from thence up our legs and buried themselves in the flesh, causing a most annoying sensation of itchiness. The whole party soon became victims to the irritation of this little pest, and scratched and exclaimed without measure. One of the Caribs, on hearing the cause of our vexation, said that the remedy was near, advising us to go without one moment's delay and lie down in the river, and that there was a small fish in the creek which would almost immediately extract the tick if it had not burrowed too far into the flesh; we all did as I fully expect you to do, gentle reader, on hearing this novel style of surgery, burst out into uncontrollable fits of laughter; but on Mr. C— and the manager assuring us that the blacks only spoke from long experience, and that they themselves had more than once proved the efficacy of the cure,—warning us at the same time that the tick, if not soon extracted, would become a very severe sore; we at last, but without one atom of faith in the experiment, assented to the proposal, and commenced to undress without further opposition.

We bathed, and then in compliance with the Carib's directions, lay down quite still in the shallowest part of the stream. In a few moments, I felt something very sharp strike against several parts of my body; cautiously raising my head, and looking down towards my legs I saw a swarm of very small fish, wriggling and swimming around me, continually bobbing their little heads at my person, and readers, ridiculous, in-

credulous as I fear my story will sound in the ears of the unlearned, positively the fish not only picked off the ticks which were outside the flesh, but actually extracted those which had burrowed beneath the skin.

No locality is given, but it must have been on some of the islands bordering the Caribbean Sea, or on the mainland part of South or Central America bordering the same sea. What the fishes were is not known. If the locality was on the mainland, these fishes may have been the young of or possibly a small species of Characin. This is conjectured on the basis of the following data:

Bearing on the origin of this habit in these tropical fishes are certain observations made by Dr. C. M. Breder, Jr., director of the New York Aquarium. Some years ago while collecting fishes in the Rio Chucunaque, Panama, and studying their habits he noted this curious and interesting behavior in a small Characin, *Astyanax vuberissimus*. These little fishes were found to be greatly attracted by human excretions and were noticeably attracted to the region of greatest abundance of perspiration—*i.e.*, to the armpits and crotch. Here they would nibble and bite assiduously at the hairs. "When these secretions had been washed away, these regions no longer possessed superior attractions and the little fishes distributed their tiny attacks over the whole body, particularly where there were warts, calluses, moles, or clumps of hair on which they could lay hold."

The region in which Dr. Breder and his men were working was not a particularly "ticky" region, and he did not see the little fishes hunting for ticks, nor did he happen on any accounts of such activities. But judging from the avidity with which the fishes attacked calluses, moles, pimples, warts, etc., he does not doubt that if men infested with ticks were to get down in the water the little Astyanax fishes would quickly rid them of these unwelcome bloodsuckers.

Ticks form a pretty steady diet for the rhinoceros birds, since all live in the same milieu—air. But flies and ticks are a most intermittent food supply for fishes, since the two kinds of animals live in the most diverse environments—air and water. For the fishes, ticks and flies come—like the manna of the Israelites—from the heavens.

SCIENCE AND SOCIETY

WHILE scientific knowledge is providing unparalleled instrumentalities for achieving an orderly and humanly significant social life, science can not minister effectively nor safely to man and his society until it is oriented to our contemporary social life and coordinated into the complex functioning of our culture. To-day ignorance of human behavior and social organization, and the prevailing unawareness of the functioning of our culture are blocking the full utilization of scientific knowledge. Thus we have the ironic and tragic spectacle of science contributing effectively to man's physical comfort or to his destruction, but seemingly helpless to advance his social and cultural aspirations.

The relation of science to society involves more than questions of the organization and immediate application of scientific results through technology and professional practice; it raises the more important issues of the place, function, and especially the responsibilities, of the scientist in the present-day social situation and cultural confusion. There is a serious lag between scientific knowledge and its application to human needs, . . . also a widening gap between scientist and layman, to whom science and technology often appear as esoteric pursuits.

Moreover, the very rapid progress of scientific knowledge has rendered obsolete much of our traditional culture and ancient beliefs and in so doing has fostered individual confusion, distortion and insecurity. Personalities so disturbed can not function adequately as individuals nor participate as members of a society which is seeking resolution of its difficulties by voluntary cooperation. The increasing social disorder, affecting those countless millions in all lands who have been cut loose from their inherited social, economic and ethical moorings, has rendered them subject to devastating exploitation by distorted, but plausible, fanatics. To-day society itself has become the patient.—*Report of the President, Josiah Mack Jr. Foundation.*

HALF A CENTURY WITH THE SUCCESSFUL ARGENTINE ANT

By ARNOLD MALLIS

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ON one fine day, fifty years ago, Ed Foster,[1] journalist and amateur entomologist, while leisurely collecting Hymenoptera, made a mental note of an innocuous-appearing brown ant. Foster, on this eventful day, devoted his entomological talents to that section of New Orleans where the coffee ships from Brazil were docked. It was not until some twenty years later, and only after the ant had become the housewife's nemesis, the gardner's grief and the orchardist's plague that he recorded his first glimpse of what is now our most prominent ant pest, namely, the Argentine ant.[2]

This insect undoubtedly was present some years prior to Foster's observation, but it only came into the public's eye with the turn of the century. The alarmed populace of New Orleans christened it the "New Orleans" ant. Newell,[3] deeming this to be a dubious honor for the Crescent City, shortly designated it the "Argentine" ant due to the fact that the species was described from workers collected in Buenos Aires, Argentina. Since the coffee ships that conveyed the ants to the docks of New Orleans came from Brazil, never from the Argentine, and since the insect was better known in Brazil, probably its native habitat, he might have called it more appropriately the "Brazilian" ant.

This most successful insect is now established throughout the southern states and in California. Isolated infestations have been reported from Arizona, Missouri, Illinois, Maryland, Oregon and Washington. It is also known from Portugal, the Union of South Africa, France, Australia and from many islands.

INJURIOUS ASPECTS OF ARGENTINE ANT

The Argentine ant is one of the most important as well as one of the most common household pests in the wide area over which it is distributed. For example, in those sections of southern California where the insect is prevalent, practically every housewife utilizes some measure to combat it. In homes where its control is neglected, hordes of this persistent creature with its ever-present trails may be found in practically any food of a sweetish nature. It is an extremely persistent pest, especially so during the warm summer months. In the winter, immediately after the rains, it may invade the home in protection from the inclement weather.

That the Argentine ant was a most serious household pest in New Orleans may well be realized when we peruse Newell's remarks anent this ant:

> The species does not sting, but can bite severely when so inclined, and sometimes becomes an annoyance to human beings. I have known of several cases where people have had to place their beds, during the summer months, upon panes of glass covered with vaseline in order to pass the night in peace. There have been rumored cases of infants being killed by these ants, but so extreme a case has not come within my observations. That such might easily occur is not at all improbable.

[1] E. Foster, *Jour. Econ. Entom.*, 1: 289–293, 1908.

[2] *Iridiomyrmex pruinosus* Roger var. *humilis* Mayr.

[3] W. Newell, *Jour. Econ. Entom.*, 1: 21–34, 1908.

Barber[4] was given this rather graphic description of the attack of the ants on a 4-weeks-old baby:

"We were awakened in the night by a weak cry from the baby, and when the light was turned on the baby's face was black with ants. They were in the baby's nose, ears and mouth. We hurriedly carried the baby to the bathtub and started to wash off the ants. It took us nearly an hour and a half to get the last ant off the baby. I feel sure that if we had not heard the cry, in a few hours the child would have perished."

Some twenty years later, Lyle[5] further indicts this insect with the following notation:

Negroes in some of the badly infested towns in Mississippi, long since accustomed to eating ants in all their food, seek partial relief while sleeping by stuffing cotton in their ears. Sleeping children with cuts on their bodies suffer especially from their attacks. The possibility of spreading typhoid fever or other diseases is indicated by their attendance on human feces in outdoor privies.

The farmer is another victim of the ant's depredations. Newell, who made the first and still most comprehensive studies of the Argentine ant, conjured a skin-creeping specter when he stated that the ant would be as bad a pest as the San Jose scale, the gipsy moth and the cotton boll weevil. Thanks to the entomologist, this dire prognostication has never been realized. In the citrus orchards of Louisiana, some thirty-five years ago, the ant was incriminated for eating the buds on the trees and thereby ruining the yield. Fig crops were likewise damaged. Moreover, this hexapod fostered aphids, mealybugs and scale insects on plants so that they increased enormously in numbers, and then these injurious insects would have the plants in a most serious way. The Argentine ant was an especially prominent pest in the citrus orchards and sugar-cane fields in Louisiana.

[4] E. R. Barber, *U.S.D.A. Bull.* 377, 1916.

[5] C. Lyle, *Jour. Econ. Entom.*, 29: 965–967, 1936.

Beneficial Aspects of the Ant

The Argentine ant has a few virtues, but these hardly compensate for its numerous vices. It is, above all else, an important scavenger of dead and dying insects. In the homes of the poor in New Orleans, it has played the role of Robin Hood by exterminating bedbugs and other vermin. The sorghum midge and other injurious insects are very often victims of its appetite. On a day in spring when the western subterranean termite conspires to populate the earth with house-consuming insects, the ant may be observed bearing the winged termite to some subterranean festive board. The ant apparently has little success against the termites when they are ensconced in their earthen tubes.

Food of the Argentine Ant

The Argentine ant has a decided "sweet tooth" which it does not hesitate to reveal when in the presence of sugars, syrups, fruit juices and materials of a like nature. It feeds with great avidity on the floral and extra-floral secretions of plants and consumes with gusto the honeydew excreted by aphids, mealybugs, scale insects, etc. Meat, especially that of other insects, is at times very attractive to it, and often one may see the ant in great numbers on a fresh bone abandoned by a dog. In Berkeley, California, the insect often invaded the university hospital and fed on blood smears. It is also recorded feeding on cereal products, especially on corn meal.

When once on the trail of food, the ant is extremely persistent. It raids refrigerators with the same abandon as any member of the family and, like Eliza in "Uncle Tom's Cabin," will even cross ice to attain its objective. The ant has been observed to drop from the ceiling on a table which had its legs wrapped in cloths soaked with coal oil, and has entered tightly screwed Mason jars, lack-

ing in a rubber gasket, by following the spiral thread between the cover and the glass.

There are certain plants which are almost certain to attract myriads of this insect, and the ants, at times, will be found ascending these plants in trails that are several inches wide. Cherry laurel is one of the "ant-plants," and the Argentine ant fondly feeds on the secretions from the nectaries on the leaves. During the summer months when the insect ascends this plant, it will not be turned aside by the most seductive of baits. Fig trees, with their fresh figs, are an ant heaven and bamboo, many species of pine, as well as numerous other plants infested with aphids and other Homopterous insects, constantly shower the hungry emmet with their "manna."

The harassed housewife is apt to attribute certain occult powers to this insect, so quickly does it locate food in the home. The ant accomplishes this feat despite relatively poor eyesight, and a sense of smell rather limited in range, so that it practically "bumps" into the nourishment before discovering it. To explain this, we need not travel into the realm of legerdemain. Newell and Barber[6] found that the ant can travel 29 inches a minute or 145 feet in an hour, and thus the scouts who forage day and night, and patrol every square inch of an infested area, are bound to contact some stray victual. They thereupon report the gastronomical bonanza to the home base, and the characteristic safari of ants ensues. In hot weather the rate of locomotion of the ant, as with other insects, is greatly accelerated, and it finds its food with even greater alacrity.

Relationship to Honeydew-secreting Insects

The economic entomologist is greatly interested in the Argentine ant because of its habit of fostering and protecting injurious insects on plants. Horton[7] clarified the relationship between the Argentine ant and a typical honeydew-secreting insect, the injurious black scale. He states:

> The ant approaches a mature or immature but settled insect and strokes the body with one antenna after the other, rapidly and rhythmically. If no liquid appears after 15 or 20 strokes, the ant usually passes to another scale or rests motionless by the first. Unless the scales are very numerous a proportion of the ants always are waiting, and the principal function of the small shelter structures found over scale groups is believed to be to protect the waiting ants from light, breezes, and sometimes, the too copiously falling honeydew and its attendant mold. When the scale is ready to excrete the anal plates open slowly outward and from between them is extruded a tubular organ, at the extremity of which appears a droplet of colorless fluid. This the ant takes and swallows at once. The tube is then retracted and the anal plates close. The whole operation requires only a few seconds, not allowing time for closer examination of the mechanism.

Horton noted that the process was somewhat similar in the mealybugs, that the ants destroyed but a negligible number of orange blossoms, that it did not disseminate the living scales, that it prevented parasites and predators of the scales from functioning, and thus intensified the effect of these injurious insects on the tree. He then concluded that as a whole the ant was not too important in citrus orchards in the building up of scale population, but was of some importance in spreading plant diseases on trees.

Students of insects have had proof for many years that ants may carry aphis and other homopterous insects on to plants and aid them in becoming established there. There is a difference of opinion amongst entomologists as to whether or not the Argentine ant actually carries scale insects on to the plant. Horton, as was previously mentioned, definitely stated that the Argentine ant

[6] W. Newell and T. C. Barber, *U.S.D.A. Bur. Entom. Bull.* 122, 1–98, 1913.

[7] J. R. Horton, *U.S.D.A. Bull.* 647, 1918.

did not disseminate the black scale. Newell and Barber came to a different conclusion, as the following observation will indicate:

During March, 1910, a considerable number of adult female scale insects were found embedded in a band of "tree sticky" placed around a magnolia tree to repel the ants. The band was located 4 feet from the ground. The scale insects were a species of *Odonaspis* which is found upon Bermuda grass close to the surface of the ground. There was apparently no other way for the insects to get up the tree except through the transporting agencies of the ants.

Relationship of the Argentine Ant to Other Ants

The Argentine ant, Genghis Khan of the emmet world, is intolerant of other species in any area it has overrun. Due to its aggressiveness, its unrelenting persistence in the attack, and especially to its superior numbers, this insect soon overcomes even the largest ant. It does not hesitate to attack the fire ant and the agricultural ant, even though they are armed with fiery stings. When the Argentine ants attack ants many times their size, they attach themselves to the appendages of their unfortunate victims; peg them out, drawing their appendages as taut as fiddle strings. Thereupon they mount the unfortunate and securely held ant; bite off its antennae, and later decapitate it.

Woodworth[8] studied the wars between the Argentine ant and its arch enemy, the odorous house ant, *Tapinoma sessile* Say. He made some interesting observations on its battles with the Argentine ant, in which he noticed that the odor

is produced by a liquid secretion (speaking of the ejection from the anal glands) which can be ejected from the abdomen as an appreciable drop, and which is used in its contests with the Argentine species. As long as the supply of the secretion lasts the *Tapinoma* has no difficulty in keeping the Argentine ant off, but after having put four or five Argentines out of the combat in this way finally the *Tapinoma* is put to rout and the Argentines are invariably victorious, because they always attack in sufficient numbers. We have observed many battles between these species and the *Tapinoma* is always driven away from its feeding ground and its home despoiled.

[8] C. W. Woodworth, *Calif. Agr. Exp. Sta. Bull.* 207, 1910.

This insect has no important natural enemies in the United States, but at times it has had some interesting contests with variable results against army ants.

Since the insect will not tolerate any sick or dying ant in the nest, there can be but little hope of natural control through artificially disseminated diseases caused by virus, bacteria, protozoa, fungi, etc.

Description of the Various Castes

It may not be amiss at this point to describe with a little more accuracy the villainness of this piece. The worker or sterile female is 2.2 to 2.8 mm long, but it may appear larger when the abdomen is extended with food. In color it varies from a light to a dark brown, with the thorax, scapes and legs somewhat lighter. The mandibles are yellowish and dentate. Often, when the worker is descending from a tree, the abdomen will appear honey-colored, due to distention of the abdomen by liquid nourishment. The worker, as its name implies, does all the work, such as excavating the nest, obtaining food, feeding the young, protecting the colony and annoying the home-owner.

The brownish queen is from 4 to 6 mm in length, and is by far the largest ant in the colony. There is usually a number of queens in one colony. One may readily demonstrate this by merely pouring a milk-bottle full of water onto a nesting site; within a short time the workers with young in their mandibles, and very often a number of queens, will emerge. Since a colony may consist of a maize of trails ramifying throughout

an extensive area, the queens may number in the hundreds.

Newell found the winged queen on rare occasions in an outdoor nest in Louisiana and encountered the alate female much more frequently in artificial nests. It was his opinion that the queen mates in the nest, making wings unnecessary. The author has yet to find a winged queen in California.

Hertzer[9] notes that the queen is not a mere egg-laying machine, but takes an active part in the feeding and grooming of the young. Moreover, in this highly successful species, the queen feeds and cleans herself.

The winged male is a small-headed, big-chested nonentity who shortly after mating departs from this vale of tears. Like other gentlemen we know, he is very fond of bright lights on warm summer nights.

Nests of the Argentine Ant

The Argentine ant has a vertical distribution from sea level to approximately 4,000 feet. Throughout its range it will be found nesting wherever there is a suitable amount of moisture in the soil, where light is excluded and where the food supply is in close proximity.

In the spring of the year the nest will often be found in open ground with small piles of excavated earth but a short distance from the nest holes. Form boards along walks, and in fact, wooden objects of any kind are preferred as nesting sites and permanent runways, as are cracks and crevices in concrete walks. The area beneath a plant infested with "ant cows" will often be honeycombed with their tunnels. The ants may be encountered in enormous numbers in and under dead and decaying stumps. During warm weather they are partial to the underarea of houses and may use the mudsills as their runways. The nest may even be established in the house proper. The queen and her following of neuters have been observed to invade the second floor of a house and to establish themselves beneath a damp rag on a kitchen sink.

The nests during the summer are usually very shallow, but 1 or 2 inches beneath the surface; on one occasion a nest was found about the roots of a tree, situated on a slope, that was more than 12 inches in depth.

In the autumn the insects aggregate into a virtual ant metropolis in which there are hundreds of queens. The huge nests may be found beneath boards, sheets of tin, buildings, etc., as well as in accumulations of dead plant material with its attendant heat of decay. The author has found the Argentine ant overwintering in enormous numbers in tunnels containing hot conduit pipes. Smith[10] noted that in northern localities this hexapod may become established in buildings, and spread from edifice to edifice, thereby avoiding the cold of winter. With the coming of spring, these colonies break up into smaller affairs consisting of one to several queens with a large number of workers all of whom migrate and establish themselves elsewhere. In fact, during the spring and summer months, an individual queen may take a stroll in the open, and upon acquiring a retinue of workers, establish her own colony.

Means of Spreading

The Argentine ant has been distributed, mainly, by "riding the rails" in products of all kinds to widely separated parts of the country. Its spread by crawling is rather slow, and Smith found this natural spread to be a few hundred feet per year. It is often introduced into hitherto uninfested areas in balled nursery stock.

That water may also serve as a transporting medium is noted by Barber, who is quoted as follows:

[9] L. Hertzer, *Ann. Ent. Soc. Amer.*, 23: 601–609, 1930.

[10] M. R. Smith, *U.S.D.A. Circ.* 387, 1936.

Lumber, rotting trees, unrooted shrubs, cane growth, fruit vegetables and all manner of refuse contribute to the mass of matter borne on the crest of flood water, and in this the ants seek refuge and are involuntarily transported. Nature has endowed this species with a remarkable habit of self-preservation from drowning in times of floods, for when rising water floods their nests and no other means of escape are presented they cluster together and form a compact ball. The immature stages form the center of this ball, with the queens and workers as the outer portion. As the ball enlarges from the addition of other workers which have been struggling alone in the water it gradually revolves. It is kept revolving slowly by the outside workers continually striving to reach the top of the ball, thus permitting air to reach the interior. The writer has had only one opportunity of witnessing the formation of a ball of this kind. After a 5-inch rainfall several balls, none more than 2 inches in diameter, were observed. According to reliable authorities, such balls have been observed on many occasions, some of them from 6 to 8 inches in diameter. The ants in these balls disperse when they come in contact with a secure resting place, such as a floating piece of timber or land, but they have been seen to float around for hours on still water.

Steamboats and driftwood in flood waters were particularly responsible in distributing the ants along waterways in the southern states.

The Argentine Ant and Its Environment

One of the most important limiting factors in the distribution of this species is the amount of moisture in the soil. The effect of a relative absence of soil moisture is very noticeable in the arid parts of the interior valleys of California, especially in the vicinity of Bakersfield, where the natural spread of the ant is very slow. Here one may observe the insect to be superabundant in and around the watered grounds of the home; yet, 2 or 3 feet away from this artificially moistened area, nests of the fire ant and of the agricultural ant are present, excellent proof that the Argentine ant is limited to the more humid soil. The immature stages are especially dependent upon a damp habitat.

Excessive soil moisture, on the other hand, caused, for example, by rains, will force the ants to seek shelter of some kind. Titus[11] noted that during wet weather in Louisiana, the ants constructed nests up in trees to which they had previously carried the immature forms. These nests were constructed with earth carried from the ground. Some of them were situated in forks of live oak trees, some 15 to 20 feet above the ground. The phenomenon of the ant carrying its whitish eggs, larvae and pupae up a plant or the sides of a house is a daily occurrence when one waters a garden infested with it. As was previously noted, the ants are very resistant to drowning. Smith records an ant colony situated on a post that was submerged for 3 days; after the recession of the water, the colony was found apparently unharmed. There is a great mortality of the ants during the winter months when the ants are numb with cold, and thus unable to adapt themselves to conditions caused by excessive rainfall. Rain, moreover, prevents the worker from foraging for food.

One may observe this persistent creature to walk on a small surface of water, especially when the water has been standing for a time, and has accumulated some dust on the surface. It may alternately walk and swim across this surface.

The ant becomes most numerous and most troublesome during the summer months. The rapid increase in numbers during a short stretch of hot weather is nothing short of phenomenal. In cities such as Bakersfield and Sacramento, California, where the maximum temperatures may rise well over 100 degrees F. for days at a time, this moisture-loving ant lives in the damp earth on the north side of the home or under the house itself. On such hot days it makes a pest of itself

[11] E. S. G. Titus, *U.S.D.A. Bur. Ent. Bull.* 52: 78–84, 1905.

by invading the house and foraging for moisture around the sink and bathtub.

The minimum temperature of our more northern localities is an important factor in confining the range of the Argentine ant. This to a great degree explains their absence from areas north of California and the southern states, except for isolated infestations where they live in artificially heated buildings.

Although cold is a limiting factor in its distribution, this originally tropical ant is at times remarkably resistant to low temperatures. Smith found that in protected places it may move at temperatures as low as freezing. He further states that he

> once found in a rotten log, packets of workers that were thoroughly encrusted with ice and were so stiff and motionless as to give the appearance of being dead. The temperature the night before had been 13°. When a mass of the workers was taken to a laboratory, they thawed out in an hour or so, without any apparently ill effect, and became as active as ever.

The writer, on one morning when frost covered the ground in Berkeley, California, wondered what had happened to a colony of the Argentine ant that had been under observation. Preliminary probing of the soil revealed naught of the ants. Further digging resulted in the removal of a clod of mud which had interesting potentialities. The normal mud ball is naturally entirely inanimate; yet this one conveyed a distinct sensation of vitality, and closer examination revealed that this effect was due to the slow flagellate-like movement of many appendages. The mud ball was then broken open, and the appendages were revealed as the antennae of the ants, hundreds of whom were thoroughly encrusted in the mud. The antennae were the only appendages capable of being moved by the frigid ants. These soon thawed out.

Herbert[12], on the other hand, found that the Argentine ant succumbs under artificial conditions of refrigeration if held for 24 hours at a temperature of 31° F. or in a shorter time if held at a lower temperature.

Air movements are quite a problem to the Argentine and other species of ants, and they will not be found foraging in open places on windy days. At these times they will seek shelter in protected places, such as under the loose bark of trees, beneath stones and in cracks and crevices.

According to Newell and Barber the ants become accustomed to loud noises and constant vibrations, and have been found "between and under the ties of railroad tracks over which many trains passed daily."

Many individuals have observed the seeming preference of the Argentine ant for electric outlets and switch boxes. Hackley[13] discovered large numbers of dead ants in household electrical outlets. When he turned off the current of the main switch the ants no longer came to the electrical baseboard outlet. When the current was turned on again, they came back. From this he concluded that the ants are attracted by the action of the electric current and are killed as a result. Is it possible that shelter and warmth may also be factors here?

History of the Control of the Argentine Ant

The evolution of the ubiquitous bottle of ant sirup or ant paste was indeed a tortuous one, and it may not be amiss to lift the veil of obscurity from those men who, if they did not make the world safe from the Argentine ant, at least helped keep them out of our homes.

The first methods of curbing this creature in the United States were rather crude, and consisted of banding the legs of furniture with tape soaked in corrosive sublimate, or using the still prev-

[12] F. B. Herbert, *Jour. Econ. Entom.*, 25: 832–833, 1932.

[13] R. E. Hackley, *Pests*, 8: 16–17, 1940.

alent ant powders, or by trapping and fumigating the nests of the ants. These methods left much to be desired, and entomologists first began to settle the fate of the Argentine ant when they interested themselves in poison baits.

Arsenic is our best-known poison, and when ants were observed to feed upon sweets, a bait of arsenic and a sugary material was naturally suggested. That the bait method of control is not a new one is revealed by Roark[14], who quotes Worlidge ("System Agricultural, the Mystery of Husbandry Discovered," 1669) as follows:

> Also you may make boxes of Cards or Pasteboard pierced full of holes with a bodkin, into which boxes put the powder of Arsenick mingled with a little Honey. Hang these boxes on the tree, and they will destroy them, make not the holes so large that a Bee may not enter lest it destroy them.

Newell[15], of the U. S. Bureau of Entomology, first pronounced the following important consideration in the control of the Argentine ant, namely, that the poison must be

> one which will destroy larvae and workers, as well as queens, within the colony. To meet this requirement the poison must be fatal but must act so slowly when contained within the insect stomach that it will not kill the foraging workers ere they can transport it to the nest and there deliver it to other members of the colony.

He had but indifferent success with a mixture of lead arsenate and sugar and honey, and lead arsenate and honey alone. He was also one of the first to announce the repellent effect of arsenical sirups, and with reference to this, states, "Our experiments have shown that solutions of sugar or molasses containing a small percentage of arsenic can be used to 'drive' the ants from a room which the foragers persist in visiting." He moreover suggested the use of one of the first weak arsenical solutions, namely, "White arsenic, $\frac{1}{2}$ gram; cane sugar, 20 grams; water, 100 cc."

At this same time, Newell notes that C. P. Lounsbury, entomologist of the Department of Agriculture at Cape Town, South Africa, succeeded "in repelling the Argentine ants from residences there by the use of very similar mixtures. Those most frequently used by Professor Lounsbury are Cooper's dip and Golden Syrup, equal parts, and a mixture of marmalade, sugar and arsenite of soda." Here mention is made for the first time of the use of sodium arsenite, the key to the control problem.

In 1905, Titus discovered the Argentine ant in Ontario, California. Two or three years later, Woodworth, of the University of California, visited Louisiana, where he studied Newell's work on the Argentine ant. In 1910, in Bulletin 207 of the California Agricultural Experiment Station, Woodworth recommended reducing the arsenic between $\frac{1}{4}$ to $\frac{1}{8}$ of 1 per cent., but he did not state what form of arsenic he used. Nickels,[16] who worked with Woodworth, stated he used $\frac{1}{4}$ to $\frac{1}{8}$ per cent. sodium arsenite in a sugar sirup. Thus it was Woodworth who definitely recommended for the first time the use of a weak solution of sodium arsenite.

Wilmon and Newell, in 1913, once again emphasized the fact that sweetened arsenical mixtures act as repellents, and were driving the colonies away instead of exterminating them.

In 1916, Barber, of the U. S. Bureau of Entomology, improved Woodworth's formula by reducing the amount of arsenic in solution. W. E. Cross, a chemist in the Sugar Experiment Station in Louisiana who worked with Barber on the ant sirup, was largely responsible for the preparation of the poison which subsequently was called the Government

[14] R. C. Roark, *Soap*, 11: 101, 1935.

[15] W. Newell, *Jour. Econ. Entom.*, 2: 174–192, 1909.

[16] L. J. Nickels, *Jour. Econ. Entom.*, 4: 353–358, 1911.

Argentine ant formula. He made a careful study of the chemical aspects of the ant sirup and was the one to suggest that

> the addition of a small quantity of tartaric acid to the sugar sirup before adding the sodium arsenite will produce a greater inversion of the sucrose, thus lessening the danger of crystallization and will neutralize the alkalinity of the sodium arsenite, preventing decomposition. If a slight acid reaction is obtained the sirup will keep indefinitely.

R. S. Woglum and A. D. Borden[17] modified the Barber-Cross formula by reducing the amount of sugar and increasing the amount of honey. This resulted in a further reduction of crystallization in the sirup. The poison bait was kept from fermenting too quickly through the addition of benzoate of soda. And with this contribution we have the Government Argentine ant formula which with slight modifications is in use to-day.

In 1924 Smith[18] and other members of the Mississippi State Plant Board succeeded, with the use of the Government Argentine ant formula, in exterminating an infestation of the ant from 1½ blocks in Fayette, Mississippi. This was the first town in the world from which the Argentine ant had been eradicated. Smith in 1936 disclosed that other towns in Mississippi had succeeded in eradicating the pests. In these instances the poisoned arsenical sirup actually exterminated rather than merely repelled the ant.

In many areas of California, particularly where intensive control is undertaken in citrus orchards, great reduction of the ant results. In other areas, control with the Government Argentine ant formula is extremely slow, and during the summer, is apparently non-existent. In such localities the ant sirup is placed around the home, where it is used as a "bribe" to inveigle the ant into feeding *outside* the house.

The greatest innovation in the control of the Argentine ant since the advent of the Government formula was the introduction of thallous sulfate (commercially called thallium sulfate) as the toxic ingredient in the ant sirup. Any individual who has used the arsenical and the thallous formulas soon becomes cognizant of the much greater effectiveness of the thallous sulfate sirup. The reasons for this increased effectiveness have not been investigated, but it is believed to be due to the fact that the Argentine ant "takes" better to the poison, and that the poison acts more quickly upon it. According to H. Hartnack,[19] a pest control operator in Chicago, he suggested the use of thallous sulfate as an ant poison to C. H. Popenoe, and with the latter evolved a formula for the control of Pharaoh's ant, *Monomorium pharaonis* (L.). Popenoe[20] published a note on this, and the sirup was subsequently used in the control of the Argentine ant. Some states prohibit the use of thallous sulfate, since it has no simple antidote.

Reasons for the Success of the Argentine Ant

What are some of the factors that have lifted this hexapod alien from the ranks of obscurity to public prominence as "Ant No. 1"?

(1) Unlike ants of most other species, the Argentine ants, even from widely separated colonies, are friendly to one another. The queens are likewise so.

(2) In an infested area it will be found that the widely separated runways of the ants eventually anastamose. Moreover, there are a great number of queens in an infested area who have a high reproductive potential. As a con-

[17] R. S. Woglum and A. D. Borden, *U.S.D.A. Bull.* 965, 1921.

[18] M. R. Smith, *Jour. Econ. Entom.*, 17: 603–604, 1924.

[19] H. Hartnack, "202 Common Household Pests," 182–183, 1939.

[20] C. H. Popenoe, SCIENCE, 64: 525, 1926.

sequence there arises an enormous number of individuals, with resultant huge and powerful colonies.

(3) The ant is extremely adaptable, and nests in a great variety of situations.

(4) There is usually no dearth of food for the omnivorous worker. The worker, moreover, is persistent, courageous and tenacious. These qualities plus their great numbers result in the defeat of practically every insect that opposes them.

(5) The female is not a mere egg-laying machine, but partakes in the grooming and feeding of the young. Almost always she mates in the nest and is therefore not subject to the perils that attend the mating flight of other species of ants. The mated female can initiate a new colony merely by walking off with a following of workers.

(6) There is no important natural enemy of the ant in the United States.

(7) Finally, they are readily distributed through natural and man-made facilities.

With apologies to Aesop and with the kind permission of the reader, may we moralize that the traits responsible for the great success of the Argentine ant in this country are almost identical with those qualities so prominent in our outstanding bipedal immigrants. These qualities are adaptability, courage, persistence and the capacity to cooperate. Fortunately for man, this ant is lacking in one prominent characteristic, intelligence!

THE SEARCH FOR UNITY

If we are to have a durable peace after the war, if out of the wreckage of the present a new kind of cooperative life is to be built on a global scale, the part that science and advancing knowledge will play must not be overlooked. For although wars and economic rivalries may for longer or shorter periods isolate nations and split them up into separate units, the process is never complete because the intellectual life of the world, as far as science and learning are concerned, is internationalized, and whether we wish it or not an indelible pattern of unity has been woven into the society of mankind.

There is not an area of activity in which this can not be illustrated. An American soldier wounded on a battlefield in the Far East owes his life to the Japanese scientist, Kitasato, who isolated the bacillus of tetanus. A Russian soldier saved by a blood transfusion is indebted to Landsteiner, an Austrian. A German soldier is shielded from typhoid fever with the help of a Russian, Metchnikoff. A Dutch marine in the East Indies is protected from malaria because of the experiments of an Italian, Grassi; while a British aviator in North Africa escapes death from surgical infection because a Frenchman, Pasteur, and a German, Koch, elaborated a new technique.

In peace as in war we are all of us the beneficiaries of contributions to knowledge made by every nation in the world. Our children are guarded from diphtheria by what a Japanese and a German did; they are protected from smallpox by an Englishman's work; they are saved from rabies because of a Frenchman; they are cured of pellagra through the researches of an Austrian. From birth to death they are surrounded by an invisible host—the spirits of men who never thought in terms of flags or boundary lines and who never served a lesser loyalty than the welfare of mankind. The best that every individual or group has produced anywhere in the world has always been available to serve the race of men, regardless of nation or color.—*Raymond B. Fosdick in The Rockefeller Foundation Review for 1941.*

CULTURE AND HUMAN BEHAVIOR

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The history of social science reveals a shifting of interest from one aspect of social behavior to another. In each successive change there has been a tendency to overemphasize the new approach, discounting even the most valid conclusions contributed by the previously popular point of view.

At one time in the history of social theory, social scientists placed a heavily disproportionate emphasis upon the rôle of instinct in social behavior. Many acts now known to be the direct outcome of long and insistent training were held to be the expressions of an instinct. This position could not be maintained in the face of the mounting evidence for cultural relativity which anthropologists were able to compile. Abandoning the instinct theory of culture, social scientists began to focus their attention upon the varying kinds of behavior which human beings exhibit. Thus, to-day, many anthropologists are concentrating upon the relativity of culture, demonstrating the wide range of variation in human learned behavior. Other anthropologists, primarily interested in the topics of culture change and acculturation, are accumulating large masses of factual evidence on such topics as invention and diffusion. Others, again, are examining the relationship between environment and culture, centering their interest upon the conditioning effect of the environment. Still others are concentrating on the transmission of culture, *i.e.*, the process by which a child learns to become a member of his society.

Anthropology is not the only discipline to center its interest around the topic of human learning. Culture historians trace changes in the customs of specific groups as they occurred over centuries of experience. Sociologists attempt to capture the trends of changing behavior norms. Other sociologists are studying societal evolution; they seek to outline the steps in a process of continuous learning which has lasted nearly two million years. To the educator human learning has always been of paramount interest. His concern is inevitably with the process of transmitting culture to the incoming members of the society. Psychologists as well are interested in the topic of human learning and some of them, indeed, have taken for their specific interest an analysis of the learning process. However, despite this universal interest in the topic of human learning, there is little coordination between the various investigations in their attack upon this problem.

For the development of a science of human behavior it seems important to concentrate specifically upon the learning process and to coordinate the tools from those disciplines which have something to contribute. Only in this way can an effective attack be made upon this exceedingly vital aspect of human behavior. The importance of understanding the human learning process can scarcely be overestimated. Without such an understanding social science predictions most probably will fail and, if it lacks predictive power, social science will remain a pseudo-science whose research workers will be regarded as parasitic eccentrics in the society which harbors them.

The human learning process is governed by rules or principles. The more

basic of these principles are well known to psychologists.[1] The essential elements of learning are (1) *drive,* (2) *response,* (3) *cue* and (4) *reward.* The *drive*[2] is the motivation which stimulates a person to act. People are in an almost constant state of unfulfilled desire. Indeed, one of the characteristics serving to distinguish between living and nonliving objects is this very incentive to action which finds its source of energy within the organism. It seems to be an unquestioned fact of human experience that mere living involves a constant striving for as yet ungratified longings and cravings. Drives may be either innate or acquired. Hunger, thirst and pain are examples of innate drives; anxiety and anger are examples of acquired or learned drives. *Cues*[3] give direction and orientation to responses. Cues may be provided by sense-organ stimulation from outside or by reactions of the organism. The *response* consists of acts, *i.e.,* what the organism does. Generally speaking the response may be considered to consist of a goal response and a series of instrumental acts. The goal response is the act immediately followed by reward; the instrumental acts are those preceding the goal response. If the response succeeds in bringing about a diminution in the intensity of the drive, the result is *rewarding.* Reward reinforces the connection between the cues and the response; an increment of learning takes place. Whenever the same drive and cues are again present, the same response will be more likely to occur. This is known as the *principle of reinforcement.* If, however, the response fails to be rewarded, then the bond between the cues and the response becomes weaker. Repetition of a response without reward leads finally to an extinction of the cue-response connections and the response fails to occur on subsequent occasions.

For human beings learning continues throughout life. New responses are learned and old ones abandoned. While habits may lie dormant for a time if they are not practiced, responses do not persist if they are tried over and over again without success. This means that customs which are not rewarding to the persons who practice them will become progressively weaker and will eventually disappear. In other words the persistence of customs depends upon their rewarding value. From this standpoint culture consists of behavior which is constantly being reinforced; it is functionally integrated with human motivation and reward. Culture is neither self-perpetuating nor self-destroying, nor are customs arbitrarily accepted or rejected; rather, they are habits strengthened by rewards or weakened by a lack of them.

Social theorists will immediately question the possibility of determining what drives are operating in any given instance. When the actions of a specific person are observed it becomes difficult to determine the drive which motivates his behavior. If a person is observed eating a meal we would probably not be too far wrong in assuming that he is motivated by hunger as modified by past learning, *i.e.,* by an acquired appetite

[1] Perhaps the most acceptable statement of these principles for anthropologists is that of N. E. Miller and J. Dollard in their recent volume, "Social Learning and Imitation" (New Haven, 1941). For an extensive account of learning principles the reader is referred to their publication. See also Clark Hull's forthcoming book, "Principles of Behavior," and "Becoming a Kwoma" by J. W. M. Whiting (New Haven, 1941).

[2] Learning always takes place under certain internal conditions in addition to drive, such as habit structure, capacity for motor behavior, and susceptibility to sensory stimulation. Important as these conditions are for any thorough analysis of a given person's behavior they will not be considered in this paper.

[3] The cue is a stimulus whose primary function is the direction of behavior, in contrast to drive which is a stimulus whose primary function is to motivate the response.

for the foods which constitute his meal. On the other hand, if he is observed attending a church service, hypotheses about his motives are likely to be the wildest kinds of guesses. More information about the person would help to substantiate some guesses and to eliminate others. Ultimately, with sufficient data concerning his life history brought to light, it might be determined that his behavior stems primarily from an acquired drive of anxiety, or perhaps a desire for prestige in his community.

If the actions of a person in a society other than our own are observed it becomes even more difficult to determine his motives. A Fijian, for example, might be observed to dye his hair black or to avoid his brother's wife. It would be a mistake to assume that the native wishes to do these things for the same reason that we would want to perform similar acts in our own society. The drives prompting his behavior may be quite different from those which would lead us to similar behavior. Only an intensive investigation will lead to the discovery of why he wants to act in this way. But the difficulty of determining the drives which operate in a specific instance does not in itself negate the importance of recognizing that behavior is motivated by drives. It points rather toward a research problem, the solution of which will add substantially to the understanding of human behavior. It is likely that operational definitions of drives will solve this problem. If drives are defined in terms of the conditions which produce them, it is not difficult to determine what drives are operating in a given situation. Hunger, for example, may be defined as a drive which increases in intensity with the number of hours of food deprivation. By discovering the length of time a person has gone without food it is possible, on this basis, to estimate the strength of his hunger drive.

Many drives are common to mankind; they accompany human life wherever it exists. Some of these drives are universal because they are a part of the natural equipment of the human organism; others are universal because they are always acquired by people during their life experiences. An exhaustive list of these universal drives has not yet been developed. Among the innate drives may be mentioned hunger, thirst, air-hunger, fatigue, sex, pain-avoidance, heat and cold avoidance and the several drives of elimination. Among the drives universally acquired through experience are anxiety or fear, anger, love, various appetites and disgusts, and probably a desire for children, a wish to be healthy and a desire for prestige. Since acquired drives are learned it is likely that their intensity varies somewhat from person to person and from society to society. This is a factual question which can be answered only by careful investigation. Nor can a list of universal drives be padded by hasty generalization from any one or a few societies. Sexual jealousy, for example, which seems so powerful an incentive to action in our society may be found to be relatively weak or even absent for the members of other societies where an entirely different set of sex mores prevail and where the training of the child is quite foreign to our own. Nevertheless, the fact that many conditions of life are common to all societies leads to the assumption that a considerable number of acquired drives are universal.

Learning always occurs in the context of a specific situation; human behavior always takes place under certain external conditions. The learning situation is as important to an understanding of the process of human learning as are the principles which have been briefly outlined above. For human beings learning situations and the conditions which compose them are many and varied. Each person lives as a member of a society

which has its own distinctive social structure and culture, and moves about on a portion of the earth's crust which has its own fauna and flora, inorganic resources, topography and climate. In brief, any human being learns in a situation which consists of all the objects, events, and energies of his immediate environment.

When a social scientist presents a monograph upon a particular society or community he presents a description of the people, the environment in which they live, their material apparatus, their social structure, their language, and their culture. From one point of view, the ethnographer presents a description of the conditions which compose the learning situations of any member of that society. Such facts as density of population, productive power of the land, and the stage of their arts and crafts are widely recognized as factors bearing a significant relationship to the behavior of the members of a society. Of importance also are the minerals, flora and fauna of their environment; the categories, groups, and institutions, constituting the structure of the society; the habits of speech and thought; the manual skills and social techniques composing their culture. These and other conditions which the ethnographer describes, are the constituent elements of any learning situation in which a member of that society finds himself throughout his lifetime. Under these conditions the people who compose that society learn to behave in certain ways; under these conditions their responses are strengthened and persist, or are weakened and disappear. The description given by the ethnographer might thus be termed his approximation to the sum total of the conditions composing any learning situation in that society.

From another point of view, an ethnographer's description of social structure, language, culture, and technology might be considered the result of a long history of learning on the part of the ancestors of the present members of the society. During the historical period forming the background of that society, millions upon millions of responses have been made by its members under stimulation from their drives. Some of these were successful under the conditions of their era, were reinforced, and were learned. Others that were tried, failed to be rewarded and were not accepted. As time passed conditions changed and responses once rewarding were no longer successful. New responses were tried and the more successful of these became accepted. During this process of societal learning, adjustments were made to the conditions set by group life as well as by the environment. Behavior patterns which might otherwise have been rewarding failed because they interfered with other and more heavily rewarded responses. The hungry men who clouted other members of society over the head to take their food were themselves set upon and punished. Through the centuries, people learned that such interference with their neighbors was not advantageous; limits were set to ingroup aggression. In the long run responses conducive to the welfare of the group were the most heavily rewarded and they persisted; many actions which were more immediately effective in reducing the drives of individuals were found to be less rewarding under conditions of group life, and were abandoned. Acquired drives and the responses which reward them reveal at any given point in time along the societal life-line the results of past learning. This process of learning still continues in each society. Each member of the society learns anew under the conditions of his environment, an important part of which consists of people whose heritage from the past is a whole series of time-tested behavior patterns.

While many of the conditions com-

posing learning situations vary considerably from society to society, others are universal. The force of gravity, inertia and friction, the changes in light intensity, temperature, humidity, atmospheric pressure, and the like everywhere accompany human life. To be sure there are variations in some of these conditions from society to society. Thus, light and dark varies with the latitude, some people are subjected to extreme variation in heat and cold, and so on. Nevertheless they are conditions universal to mankind. Also significant to all people are the conditions presented by human physiology. In all societies women menstruate, conceive, and give birth to their young; people become sick, grow old, and die. Such events as these supply a host of conditions common to all mankind. In every society, moreover, there are aspects of social structure and culture, products of societal evolution, which are common to all societies. Such, for example, are categorical differentiations based on sex and age, the basic family group, the use of language; all societies forbid incest, ingroup murder, theft and rape; and all societies have their methods of obtaining and preparing food and drink, techniques for the manufacture of material goods, and accepted ways of obtaining sexual gratification.

The amount of detail into which an ethnographer can go in describing the life conditions of the society under his observation is limitless. This becomes at once clear if the difficulty of describing a single learning situation be envisaged. Any given situation could presumably be described in terms of all its various conditions, but such a description would be almost endless, since the details which might be included are exceedingly numerous. From the standpoint of human learning, however, it is not necessary to ferret out the very last detail of a given learning situation. It is important only to consider those conditions which are relevant to the learning process. If a child is learning to nurse from a bottle, for example, such conditions as the fullness of the moon, the time of year, and the number of chairs in the room are probably irrelevant. On the other hand the shape and appearance of the bottle, the words uttered by the mother, and the taste of the milk are likely to be of paramount importance.

If it is true, as it seems to be, that some conditions are more important than others from the standpoint of human learning, by what criteria can one determine the relative importance of these conditions? The relevance of conditions to learning depends upon their relationship to the four crucial factors of drive, cue, response, and reward. In the example given above, it is highly doubtful that the fullness of the moon, the time of year, and the number of chairs in the room bear a significant relationship either to the child's drive or to its response, nor do they directly furnish cues or appreciably affect the reward. Moreover, these conditions are not likely to remain the same whenever the child is nursed. By contrast the shape and appearance of the bottle, the mother's speech and the taste of the milk all consistently accompany nursing and probably perform at least one significant function, namely, that of providing the child with distinctive cues.

The conditions composing a situation may be important as the source of cues to which the response becomes attached during learning. A person receives many of his cues from his environment. The importance of conditions in providing cues is perhaps most clearly brought out by contrasting different learning situations. For example, people may learn to react with friendly approach tendencies in situations where members of their own society furnish the primary cues for their behavior. If

the same people find themselves in a situation where members of another society are present, the more similar these foreigners are to the members of their own society, the greater will be the tendency to react with friendly approach tendencies. Thus if the foreigners are of a similar physical type, wear similar clothing, exhibit similar haircuts, and the like, the tendency to react with friendly approach tendencies will be exceedingly strong. The difficulty in discrimination thereby arising depends upon the similarity of the primary source of the cues in the two situations. If the foreigners are deadly enemies, the mistake is likely to be very costly. Faced with such a difficulty many people have learned to differentiate themselves from their dangerous neighbors, thus facilitating cue-discrimination. Devices serving this function are, for example, special types of clothing, different forms of headdress, and tattooing. Language affords another device: those who belong to the ingroup may be designated by a word such as "friend," whereas those belonging to the outgroup may be given a term such as "enemy." Such words are responses with specific learned cue-value. The use of such terms permits rapid discrimination between conditions which are otherwise quite similar as sources of cues.

Quite apart from their relevance as sources for cues, the conditions of a learning situation may be important for learning because they affect the drive. Indeed, external conditions may be the primary basis of drive stimulation. A very loud sound, a bright light, cold air, the heat of the sun's rays, a knife pressing into the skin, or the pressure of a heavy weight are examples of external conditions which may produce internal stimuli of drive value. Acquired drives are often evoked by external stimuli: danger signals evoke anxiety, taunts, anger, and the death of a loved one grief. Somewhat more indirectly the intensity of drives already operating may be increased because of the external conditions. Thus, lack of food, air, water, or a suitable sex-object will result in an increase in the intensity of internal drives.

In direct contrast to the rôle of conditions in increasing the intensity of a drive is the relationship which they bear to reward. Conditions may serve to reduce the intensity of the drive and thus produce a rewarding state of affairs. A person stimulated by a loud sound is rewarded when the noise ceases; a person driven by the pain of a knife pressing into the skin is rewarded when the knife is removed; a thirsty person finds his drive intensity reduced when water trickles into his mouth and throat; anxiety is reduced when the danger signal disappears. Learning is primarily dependent upon the rewarding function of conditions for, unless a reduction in drive-intensity takes place, learning does not occur.

The conditions may also be important to learning because they limit the kinds of responses which a person can make. This is most obvious in the case of a man bound hand and foot to an electric chair or placed in a padded cell. But external conditions other than bonds and jails restrict responses. A primary instance is gravity, a limiting condition which man is never able to escape. Because of gravity he can jump only so high, finds himself unable to fly without mechanical apparatus, and so on. Responses are also limited by the fact that of all the things which might conceivably enter into human behavior only a few may exist in the surrounding environment. The house which man may learn to build as a means of providing warmth and shelter in a frigid climate can only be constructed of the available materials. People can not learn to make pottery if there is no clay. Where animals which

can be domesticated do not exist, no pastoral culture can develop. Furthermore, not all the things which the environment actually contains may be available at a specific stage of development. The techniques which have been developed in material culture may not provide for the extraction of certain materials which would be available with different and more advanced technological processes. Iron may be extracted from certain ores, but if the technological processes of smelting and the like are unknown, the iron may remain so hidden that for all practical human purposes it might just as well not exist in the environment. Until such processes are learned, or until iron is introduced from another society, responses which involve the utilization of iron can not be learned.

From this analysis it becomes clear that external conditions are relevant to the process of human learning if they provide cues, affect drive stimulation, or govern the responses which the organism can make. Implicit in this analysis is the assumption that learning only takes place in a situation which poses a problem. A problem arises when the situation is not immediately rewarding, *i.e.*, when the conditions do not permit a successful goal response. By this definition a problem consists in learning how to change a nonrewarding situation into a rewarding one. It is the function of behavior to make this change, thus solving the problem. If the situation is immediately rewarding, no problem exists. The drive is reduced without intermediate instrumental responses and learning does not occur. If the situation is *not* immediately rewarding then a problem exists. If a response is then made which solves the problem, *i.e.*, changes the nonrewarding situation into a rewarding one, learning occurs. Learned behavior therefore consists of problem-solutions.

The nature of the drive immediately marks out and specifies in advance the types of conditions which will permit reduction in the intensity of that drive. Thirst, for example, can only be diminished if the situation provides a suitable liquid. Hunger, likewise, demands certain specific conditions for its reduction. Similarly, fatigue, sex, and pain-avoidance drives mark out a limited number of rewarding conditions. Conditions vary in their capacity for drive reduction within the band of tolerance set by the drive-specifications. Though a person may be able to get some rest sitting in the seat of a cross-country bus, his fatigue drive will be more adequately reduced if he can stretch out in a comfortable bed. The specifications set by a drive thus rank conditions in a hierarchy in accordance with their drive-reducing value. If the specifications are known it is possible to predict which one of the experienced situations will be preferred.

In real life basic and innate drives seldom operate in their virgin state, unelaborated by past learning. People generally respond under the stimulation of basic drives as they have been modified by previous rewarding experiences. Acquired drives set more elaborate specifications than do the basic and innate drives. The desiderata imposed by thirst or hunger, for example, are less exacting and complex than those set by an acquired appetite for French wine or Swedish cooking. Those acquired drives which motivate instrumental responses leading to drive satisfaction are especially likely to set elaborate specifications. As drive-specifications become more detailed, the number of possible rewarding conditions decreases. An example from technology will suffice to clarify this point. If a man desires a receptacle, that is, something which will hold something else, the number of possible rewarding conditions is great. If, however, the drive-specifications are more complete and detailed

the number of possible rewarding conditions is greatly limited. If he wishes a receptacle that will hold water and will, at the same time resist fire, the number of possible conditions which permit the solutions to his problem is severely restricted. This is a well-known principle in modern technology. Sometimes, indeed, the specifications are so precise and detailed in the manufacturing processes of to-day that it is possible to devise only one way of achieving the desired result.

It is with respect to acquired drives that the advantage of knowing the specifications which they set becomes most apparent. Only if the drive-specifications are known can one adequately identify acquired drives. The desire to have children in one society can only be compared or contrasted with a similar desire in another society if their respective specifications are known. In one society it may be of paramount importance that the child born be a boy, that it be born in wedlock, and that it show no blemish on its skin. In a second society the drive-specifications may be quite different. Here the preferred child may be a girl, legitimacy may not depend on wedlock, and birthmarks may be greeted with approval.

Given a certain set of drive-specifications, the response which will be successful is one that so changes the conditions of the situation that a rewarding state of affairs is reached. The kinds of response which will be rewarded, therefore, depend upon the change in conditions required by the drive-specifications. Sometimes this change is relatively simple and a response is at hand to take care of the problem. A baby is born into an atmosphere of air. Once the baby breathes, air is drawn into his lungs. Conditions are such that the simple response of breathing does not fail. To attain a rewarding state of affairs is easy; the problem is solved by the breathing mechanism. But if circumstances are altered and the baby falls into the lake, the same mechanism sucks water into his lungs. The response fails dismally. Such a change in conditions poses a more difficult problem. Some new response must be made if he is to get air into his lungs instead of water. In solving this problem swimmers learn to hold their breath for a short time and then so to twist their bodies and move their hands and feet that they come up for air. Modern technology provides devices which permit a portion of the air to be taken beneath the water so that breathing can continue. Diving suits and bells, submarines, and the like are solutions to the problem imposed by the conditions for breathing that man finds under water.

In order to be effective in changing conditions, the response must conform to the requirements imposed by the laws governing such changes. An attempt to drink water out of a sieve will fail. The same act, if a cup is used, will be successful. An attempt to blow out an acetylene torch which is burning the skin will not be followed by reward. The same act, however, will successfully snuff out a match which is too near the finger. The success or failure of a given act in bringing reward thus depends upon its effectiveness in changing the conditions. But what are the laws which govern the effects of responses upon conditions? If these laws are known, together with the drive-specifications and the immediate state of the conditions, it will be possible to predict what responses will be successful and hence can be rewarded.

Laws govern changes in types or classes of conditions. Each specific learning situation is different from all others. The identical constellation of conditions probably never recurs exactly on two different occasions or for two different persons. But while par-

ticular conditions are never precisely duplicated, types of conditions are repeated both spatially and temporally. These types depend for their definition and recognition upon the abstraction of certain characteristics. Thus one bit of metal may be classed with another bit of metal as of the type *iron,* because of certain characteristics which they both share. For the purpose of identifying these two bits of metal as iron, the peculiar and individual characteristics of each bit are disregarded. The arrangement of one crowbar placed against a stone is classed with that of a digging stick placed against a block of wood as being of the type *lever.* The significant characteristic in this instance is the pattern of arrangement, *i.e.,* the position of the bar or digging stick with respect to the stone or wooden fulcrum; other characteristics are ignored. The motion of a falling stone is classed with any other moving body whose velocity is increasing positively on the basis of the type of motion, in this case *acceleration,* which they have in common.

Types of substance, pattern, and motion have been the basic subject-matter of science. Scientific laws are the principles governing the relationships between established types. The existence of a large body of knowledge concerning the principles governing the types already established by the various sciences may well be of enormous assistance to the study of the part played by conditions in the learning process. It seems desirable, at the outset at least, to examine learning conditions in the frames of reference provided by the existing sciences. While any grouping of the various sciences must be arbitrary from a logical standpoint, conditions are classified here into the following divisions: (1) those types of conditions whose laws are being developed by physics and chemistry will be termed physico-chemical conditions; (2) those types of conditions whose laws are being developed by biology and physiology will be termed bio-physiological conditions; and (3) those types of conditions whose principles of relationship are being developed by the social sciences will be termed psycho-social conditions.

Physico-chemical conditions consist of types of substance, pattern, and motion defined in certain characteristic ways. Substances, for example, are typed in physics and chemistry by such characteristics as density, mass, tensile strength, atomic and molecular structure, acidity, melting point, and the like. All known substances may be typed in physical terms, while only a few inert masses escape refined classification into chemical types. In other words both organic and inorganic substances may be defined in physico-chemical terms as condition-types. Physics and chemistry thus classify into common types such noticeably dissimilar objects as human beings, trees, lumps of earth, and billiard balls. Whenever a problem-solution demands effective changes in the physico-chemical condition-types of the situation, the responses must be in adjustment to physico-chemical laws.

Bio-physiological conditions consist of types defined according to different characteristics. Substances, for example, are classified into types by biology and physiology on the basis of such traits as growth, metabolism, cellular and anatomical structure, and the like. Biophysiology deals only with organic conditions; all nonliving substances are excluded. Whenever responses must deal with bio-physiological condition-types, they must be in adjustment to biophysiological laws if they are to be effective. Thus if drive-specifications demand a change in the physiological state of the human organism, responses will be successful if they conform to the laws governing such a change. A person ill

with pneumonia, for example, can only get well by following the rules set by physiology as effective in assisting a return to health.

Psycho-social conditions include a still narrower range of phenomena. Psychology types only the higher order of mammals and the social sciences restrict their types to human beings. Social anthropology has gone far toward establishing types of conditions within the psycho-social realm. These condition-types are conveniently described in terms of social structure and culture. The social structure of a society has to do with the units which compose the society and the relationship between them. The persons who compose a society may be typed as members of categories and groups. A person belongs to a category if he shares with other persons some significant characteristic which is correlated with his responses. The trait of sex defines such categories for every known human society. Other characteristics used as the basis for categories are age, kinship, pregnancy, and the like. Groups differ from categories in that they are organized. A universal group for the human society is the family. The social clique, the functional unit of social classes in our own society, is another example.

Culture consists of traditional ways of solving problems. Some problem-solving responses are common to certain categories, and others to certain groups. In describing the culture of a community in the United States, for example, the social anthropologist would determine the distribution of culture by the categories and groups to which the persons of the community belonged. Within that community the effectiveness of responses in changing psycho-social conditions depends upon knowing what responses other people will make. The prediction of what other people will do in response to one's own behavior is made possible by a knowledge of the categories and groups within the society. Thus, for example, a person seeking advice about how to get well from an infection can predict that he will be more successful if he consults a doctor rather than a lawyer.

By casting types of conditions into the framework of the sciences which deal with them, it is possible to specify the laws which govern the effects of behavior on those conditions and to predict in advance the kinds of responses which will fit the drive-specifications. Sometimes, however, a change in the conditions occurs following responses which have no, or very little, direct relationship to the responses. This permits the reinforcement of nonfunctional responses. Because of this it is possible for magic and ritual to be rewarded. Instances of this chance reinforcement abound in life experience. Control of the weather is a famous example. The rainmaker carries out a procedure which is supposed to bring rain; sometimes shortly thereafter rain actually falls. The magical behavior which preceded the rainfall is rewarded.

A few examples will clarify this problem-solving aspect of behavior. When a hungry, thirsty baby sucks at the nipple of a nursing bottle, he pulls milk into his mouth and then swallows it. This change in the situation reduces the baby's drives of hunger and thirst. Learning principles tell us the effect of this event on the future behavior of the baby. Since his behavior is rewarded the cue-response connections are strengthened and an increment of learning takes place. The next time a similar situation is presented to him the sucking response will be more likely to occur than before. To understand fully this sample of learning, however, it is important to know just how the sucking response happens to be rewarded. Had the baby been driven by pain produced

by a pin sticking into its leg, instead of by hunger and thirst, the sucking response would not have been rewarding. Sucking fulfills the drive-specifications set by hunger and thirst, but not those resulting from a pin sticking into the leg. The response also conforms to the requirements set by the conditions. By suction the milk is pulled out of the bottle and into the child's mouth. The conditions happen to be such that sucking at the nipple is successful in solving this problem. If there were no milk in the bottle, if the nipple were impervious to milk or so rigid that the baby could not squeeze it with his tongue and gums, the response would fail. In this latter case the conditions would impose requirements upon the behavior of the child which would not be met by the sucking response. It will be noted that the condition-types changed by the response in this example fall in the physico-chemical realm. That is to say the requirements of the problem solved by the behavior can be described in physicochemical terms. If, however, the situation were different other kinds of requirements might be imposed upon the child's behavior. Such would be the case, for example, if part of the baby's problem were to bring the bottle within reach of his hands and mouth. The solution to this problem might be to cry —a response dependent upon psychosocial condition-types for its success. The effectiveness of crying in changing the situation will depend upon whether or not he is heard by a nurse who has learned to respond to his cries by bringing the bottle to him.

As another example, the problem of changing the position of a heavy stone may be considered. This problem can only be solved by some response which conforms to the physical laws governing the motion of masses. Yelling at the stone, calling to it, spitting on it, and many thousands of other possible responses will fail. Why? Because to move the position of a heavy stone requires the application to it of a pressure greater than its own weight. If the person is strong enough the stone may be moved by lifting, pulling, or pushing it by hand. Such responses, however, require considerable effort and, therefore, the drive to move the stone must be greater than the counter-drive to avoid fatigue. The stone can be more easily moved by using a lever. Once this solution is tried, it will be preferred if it is easier to procure a lever and then use it, than it is to lift, pull, or push the stone.

If, instead of a stone, a person wishes to bring a wild pig to the village from the forest his problem is more complicated. Though the pig may weigh the same as the stone, the former differs from the latter in that it can move of its own volition. Conceivably the fact that the pig can move by itself might be turned to good account. The pig might be lured to the village. Whether or not this will be successful depends upon the laws governing the behavior of wild pigs. If the pig is hungry enough and if its tendency to avoid human beings is not too strong to overcome the tendency to approach food, the hunter could drag food in front of the pig and thus entice it to his village. Another way of solving the problem is to nullify the requirements imposed by the way in which animals behave. This can be done by rendering the pig powerless to move by itself. Thus the hunter might lure the pig into some kind of trap (one which the pig will not have a strong tendency to avoid) and then truss its legs in such a way that it can not move. Or he could poison the pig, render it unconscious with a blow, or kill it. Such responses change the conditions to the extent that the pig can now be treated exactly like a stone. The conditions determining the successfulness of the hunter's response have been changed.

The requirements of his problem now permit responses which succeeded in moving a stone to be effective in moving a pig.

If a warrior wishes to bring home the body of an enemy human being, instead of a pig, his behavior must conform to still more complex requirements. He is dealing not only with a heavy mass like the stone, not only with an animal which can move of its own volition and can be dangerous to his welfare like the pig, but also with an animal who is a member of a society. As a member of another society, the enemy is likely to have comrades-in-arms who will come to his assistance. To deal successfully with the problem, therefore, the warrior must make responses which will cope adequately with the complications arising out of the position of his enemy in an alien society. Requirements from the psycho-social realm are added to those from the bio-physiological and physico-chemical to which his behavior must conform if his response is to be successful. In adjustment to these new requirements the hunter may prevail upon his friends to enter the alien country on a raiding expedition, thus adjusting to the cooperative effects of his enemy's comrades in defense. At the same time, he may choose to make the raid in the early hours of the morning when he knows it is the custom for his enemies to be sleeping. Such responses are in adjustment to the additional requirements imposed upon his problem by the fact that the enemy, unlike the pig and the stone, is a member of another society.

It will be noted that certain requirements imposed upon the warrior's behavior depend upon the way in which the enemy reacts to the situation. When the enemy sees the warrier he will act as he has learned to act when he sees a person whose characteristics identify him as a warrior from a hostile tribe. The enemy will thus identify the stranger as a hostile warrior and this will be the cue to a specific set of learned responses. If the warrior could avoid being placed in this category, or delay such recognition, he might partially nullify the requirements imposed upon his responses by the reaction to him on the part of the enemy. This explains in good part the advantage of responses such as sneaking up quietly upon the enemy, using camouflage or disguise, and attacking when the light is so poor that it is difficult to see.

It has been pointed out that human behavior is learned according to the principles of learning. Learning principles always operate in a learning situation composed of certain conditions. The conditions composing such a situation are relevant to the learning process if they provide cues, influence drives, or limit possible responses. Moreover, learning only takes place in a dilemma, *i.e.*, when an organism is faced by a problem. Problems arise when the drive-specifications are not immediately met by the existing situation. The problem thus posed is one of changing the conditions of the situation so as to bring about a rewarding situation, *i.e.*, one which will fit the drive-specifications. In solving such problems, responses must conform to the laws governing changes in the condition-types involved if they are to be successful. Those responses which are consistently followed by successful changes in conditions are the ones which are learned and persist. Culture, therefore, is composed of responses which have been accepted because they have met with success; in brief, culture consists of learned problem-solutions.

COSMIC EMOTION

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EVERY one of us is born into a wonderland—the universe in which we live and move and have our being, and which, from the dawn of human thinking, has exerted a profound fascination upon the mind.

Man's reaction to the riddle of the universe is an interesting study, leading to a conclusion perhaps rather unexpected—that in this respect modern man differs less from his primitive forbears than might be supposed. An analysis of the cosmic emotion evidenced in the earliest human records reveals six principal elements in its composition, five of which are to be found in modern man, all qualitatively unaltered, though in some cases much intensified. The sixth element, though strong in earlier times, has now almost faded away, but its place has been taken by a seventh element of distinctly modern origin.

First and foremost among these permanent elements we may place wonder and its invariable concomitant, curiosity. The presence of these elements in very young children testifies to their ancient racial character. It is recorded that the physicist Clerk Maxwell, in his early years, was continually asking his elders: "What is the go of that?" Every parent can match this from his own experience, and primitive man doubtless asked many such questions with no one to answer them. But curiosity, like hunger, becomes stronger the longer it remains unsatisfied, and lacking an answer it will manufacture one for itself.

The records of the past are full of such guesses at the causes of natural phenomena, mostly anthropomorphic in character. The stormy waves of the sea were caused by the wrathful strokes of Neptune's trident; the attraction of the magnet for iron was due to an indwelling spirit, and the thunderbolts of Jove still live in poetic parlance. Gradually, however, man learned that there was one source from which he could obtain an answer to his questions—nature herself. It has been well said that an experiment is a question put to nature, and it is interesting to reflect that the experimental method and the growth of modern science have their origin in the urge of these two primitive instincts—wonder and curiosity.

Primitive though they may be, these elements are still with us. Time has but strengthened and ripened them, and widened their field of application. It is no longer necessary that an occurrence be rare or spectacular to excite our wonder. We have learned that the simplest and most commonplace natural phenomenon, even the falling of an apple from a tree, is, when we stop to think about it, as Newton did, wonderful past all speaking. Nor is this recognition of the wonder of the commonplace confined to scientific men.

Seventy years ago, some of William Kingdon Clifford's most successful popular addresses on science were given before audiences of London working men. It is true that Clifford was the greatest master of lucid exposition in our language, but some of the credit must be given to the receptive audiences. It is unthinkable that even a Clifford could interest, say, a primitive group of Australian black-fellows in such subjects without the liberal use of experiments according to the classical definition—involving a bright light or a loud noise.

Several years ago I was asked to de-

liver an address before the scientific staff of the General Electric research laboratory at Schenectady, and also to make a popular broadcast from their radio station. As a subject for the address to the staff I suggested: "Old and new ideas about gravitation," and for the radio broadcast: "Practical suggestions for improving the acoustics of buildings." I was advised by the management of the radio station to use the same subject for the broadcast that I had chosen for the staff meeting, as their experience told them that it would excite the greater popular interest.

The third element in man's cosmic emotion is reverential awe. This also dates back to remote antiquity, as is evidenced by the world-wide prevalence of sun worship. With the passing centuries this element has lost none of its strength. It has been a favorite theme of the poets, ancient and modern. The words of the Psalmist are familiar to us all:

> The heavens declare the glory of God, and the firmament showeth his handywork.
> Day unto day uttereth speech, and night unto night showeth knowledge.

Three thousand years later Tennyson expresses the same feeling:

> Flower in the crannied wall,
> I pluck you out of the crannies:—
> Hold you here, root and all, in my hand,
> Little flower—but if I could understand
> What you are, root and all, and all in all,
> I should know what God and man is.

Closely connected with this element of reverential awe and, in fact, a corollary to it, is man's feeling of his own insignificance as compared with the physical universe. David gives expression to this also:

> When I consider thy heavens, the work of thy fingers,
> The moon and the stars which thou hast ordained,
> What is man that thou art mindful of him?

With the growth of our knowledge of the universe this feeling of our own physical insignificance has been greatly intensified. It is perhaps not generally realized how small the ancients believed the universe to be. The Greeks placed the abode of the gods no farther away than the summit of Mount Olympus. Omar Khayyam complains of his cramped quarters:

> And that inverted Bowl they call the Sky,
> Whereunder crawling coop'd we live and die—

A legend of the days of Mohammed tells how the Prophet made a round trip to heaven and back in one night, mounted on a miraculous steed, to confer with Allah about the number of prayers to be required of the faithful. Even allowing for the element of the miraculous, such a legend could hardly have taken root and flourished in the environment of our modern ideas of the size of the universe. Contrast the ancient concept of the universe with that of the present day, and we can begin to appreciate how much this feeling of physical insignificance has been intensified

But no matter how insignificant an individual may feel, there is a certain measure of compensation in feeling one's self to be a member of a large group, and the larger the better. For this reason speculation as to the possibility of intelligent life elsewhere in the universe has been particularly attractive to our earth-bound race.

A generation ago there was much discussion of the question of possible inhabitants of the planet Mars. Little is now heard of this in scientific circles. Cosmically speaking, life as we know it is a delicate hot-house plant, capable of existing only within rather narrow limits of temperature and composition of atmosphere, and every increase in our knowledge of these conditions as they prevail on Mars has made the existence of intelligent life on that planet more and more improbable. The same applies to all the other planets of our solar system; they are either too hot or too cold, or their atmospheres lack sufficient oxygen and water.

But are not the stars of heaven suns

like our own, and among these millions of suns and their attendant planets is it not reasonable to suppose that there may be a few thousand bodies as well fitted as our earth to sustain human life?

For this question astronomy has rather a staggering answer. It is true that these stars are suns, but it does not necessarily follow that they all have planetary systems. It fact, it is now regarded as quite possible that but very few of them are so favored. Jeans goes so far as to call our system a freak system, and to suggest that there may be but one other like it.

There is to-day no perfectly satisfactory and generally accepted theory of the origin of our solar system. That the planets once formed part of the sun is beyond doubt, but how they came to be detached from it is still uncertain. Laplace's nebular hypothesis, after a reign of more than a century, had to be abandoned, as it was found that it failed to satisfy an important condition of celestial mechanics. Several other hypotheses have been proposed, none of which is completely satisfactory, but all of which agree in ascribing the origin of the solar system to a close approach or a grazing collision between our sun and another star. And so widely scattered are the stars of heaven that such an encounter could not be expected to occur oftener than once in ten million million years. Our little colony of life may be only an ant hill in a vast desert, and man's feeling of physical insignificance is intensified by a sense of cosmic loneliness.

These four elements—wonder, curiosity, reverential awe and physical insignificance, have been features of man's cosmic emotion since earliest times, and bid fair to remain so as long as our race shall last. Such changes as time has wrought in them have been quantitative, in most cases an increase in intensity. To these four is to be added a fifth, which, though prominent in bygone years, has now almost faded away—superstitious fear.

During the Middle Ages it was the universal custom in Europe to ring the church bells on the approach of a thunderstorm with the idea of frightening away the Prince of the Power of the Air and his attendant demons. Bells are still to be seen in old churches bearing inscriptions such as "I break the lightning," or "I put demons to flight." In earlier days this fear often prompted human sacrifice in times of famine or pestilence, to appease the supposed anger of the gods. In some places, on the principle that prevention is better than cure, a human victim was sacrificed annually in the spring of the year in order to ensure fertility of the fields during the coming season. In our time this element of superstitious fear has all but disappeared, but its place has been taken by another element, qualitatively new, and of distinctly modern origin.

The supposed agency of demons and spirits in natural phenomena has, with the modern development of the sciences, been replaced by physical causation and laws of nature. These laws are now so well understood that we can, for instance, predict with reasonable accuracy a clear or rainy morrow, and with perfect accuracy an eclipse of the sun. Passing from the macrocosm to the microcosm, we have learned the cause of many diseases and the cure for some of them. We prefer lightning rods to church bells and antitoxins to incantations. Though much of nature is still beyond our prediction or control, it is no mean attainment to have achieved a sufficient intellectual mastery of our environment to begin to understand it. And as we pass the Cosmos in review before the mind and reflect that of all nature man alone has achieved this mastery, there wells up within us a sense of intellectual superiority that goes far toward alleviating our feeling of physical insignificance. Man may be but the merest speck in the universe, yet in his intelligent comprehension of it is he not but little lower than the angels?

In the year 1875 the physicist Maxwell gave this growing feeling of intellectual superiority a powerful stimulus.

The more we have learned of the laws of nature the more profound is the respect which they have inspired. Like the laws of the Medes and Persians, they alter not. We may defy them, but no one is sufficiently influential to escape the consequences of his defiance. Such progress as we have made in the control and utilization of natural forces has been attained by making allies of some of them, and cunningly pitting one force against another, as, for instance, the air resistance to a parachute against the force of gravity on the aviator. Imagine then the effect produced in the scientific world when Maxwell pointed out that it lies within the power of intelligence to reverse the action of one of nature's fundamental laws, known as the second law of thermodynamics.

According to this law heat, like water, when left to itself, naturally runs down hill. If we put a cold spoon in a cup of hot tea the spoon becomes warmer and the liquid cooler. This transfer of heat from the higher level of temperature to the lower will continue until both spoon and liquid reach a common level of temperature. It would be against all experience to expect the spoon to become colder and the tea hotter.

It is true that water can be raised from a lower to a higher level, but only by expending work upon it, as, for instance, by lifting it in a bucket or by working a pump handle. And it is possible to make heat run up hill from a cool body to one that is warmer, but, as with water, only at the price of expenditure of work. But Maxwell showed that it is theoretically possible for intelligence to bring this about without expending any work. The practical difficulty is that we lack for the present a vision keen enough and a touch delicate enough to see and handle the single molecules of which all bodies are composed.

Of the three states of matter, solid, liquid and gaseous, the structure of a gas is the simplest, and it was upon this that Maxwell based his demonstration. Imagine a swarm of bees flying about in a closed box, colliding with each other occasionally, and rebounding from the walls of the box. Suppose also that some of the bees are flying rapidly and some slowly, while the majority are flying at intermediate speeds, and you will have a good idea of the structure of a gas. The molecules of which a gas is composed are, of course, very small, far too small to be seen with a microscope, but their number is so great and their velocities so high (of the order of a mile a second) that the pressure produced by the joint impact of millions of these molecules upon the walls of the containing vessel is by no means inconsiderable. This it is, in fact, which sometimes bursts a steam boiler.

When we say that a gas or a vapor is "hot" it is our way of expressing the physical fact that its molecules have a higher average velocity than those of a cooler gas. The molecules of the hot steam inside the boiler are moving much more rapidly than those of the air outside, and the pressure on the boiler plates from within is greater than the counter pressure from without. The wall of the boiler is supposed to be strong enough to take care of this difference of pressure, but if the water is kept boiling vigorously the number of steam molecules continually increases until their joint impact is so great that the boiler plates give way.

Returning to Maxwell's argument, imagine a gas contained in a vessel divided into two parts by a partition, and suppose the gas on either side of the partition is at the same temperature, that is, the molecules on each side have the same average velocity. Suppose that there is a tiny door in the partition, in charge of a little intelligent being who can see the molecules and distinguish between the

rapidly moving and the slow ones. When this being sees a rapid molecule in the right hand compartment headed for the door it is his duty to open the door, and let the molecule pass into the left compartment, but he is to keep the door closed against slow molecules on the right. Conversely, he is to allow only the slow molecules to pass from left to right. By this sorting process the average velocity of the molecules on the right will continually decrease, while that of those on the left will increase. The effect of this will be that the temperature of the gas on the left will rise while that of the right will fall, and heat will run up hill.

This argument of Maxwell's is something more than an interesting fairy tale. It teaches us that when, from our experience, we have formulated what we call a law of nature we are not to regard this as the last word on the subject; that nature's way of working when left to herself may be radically altered when intelligence takes the reins. Nor is the necessary degree of intelligence to be regarded as an unattainable ideal. Much progress has been made in this direction since Maxwell's day, and more will be made in the future. While we are not yet able to see molecules we can do many things with them without seeing them. We can, for instance, count the number of molecules in a cubic foot of a gas with at least as great accuracy as we can count the population of New York City.

There is much justification for the feeling of intellectual superiority with which man surveys his environment. The intensity which this feeling may attain is well illustrated by an old story.

It is said that at one time an astronomer discovered a new star, which he found by his measurements to be approaching the earth with a high velocity. He calculated that it would strike the earth in a few months. He did not announce his discovery, fearing to witness the orgy of lawlessness and despair which might follow such an announcement, but night after night he studied this approaching doom, fascinated by it. One night he spoke out and addressed the star as follows:

"I know that you will soon destroy me and everything living, but I can calculate the day—nay, even the hour when this will happen, while you are but a blind, brute thing, and I would not change places with you!"

There is one more element in our cosmic emotion to be considered. Man finds himself in a wonderland which excites curiosity and inspires awe. He feels his own physical insignificance and the transitory nature of his stay, and yet he is not content to be a mere "super" in the cosmic drama, but feels qualified for a speaking part. He wants to be remembered, he feels an urge to leave his mark on the universe, at least upon such portion of it as is within his reach.

We can trace this element far back into antiquity. This it was which built the pyramids, and which prompted the proud boast of the Roman emperor who said: "I found Rome of brick, and left it of marble." In modern times this element has suffered a qualitative change, and has assumed a form less materialistic and more altruistic, but the primitive urge is still there. When the founder of the Smithsonian Institution made his will by which his estate was left to the United States of America, "for the increase and diffusion of knowledge among men," his solicitor expressed surprise at this unusual bequest. Smithson replied: "My name will be known among men when the Percys and Northumberlands are forgotten."

But after all, such monuments, physical or intellectual, can affect only a tiny fraction of the universe—our earth and its inhabitants. In ancient times, when the earth was regarded as the most important part of the visible universe, one might reasonably feel that in beautifying a city or in bettering human society he

had done something of cosmic importance, but with our broader outlook the case is different. Not that this detracts in the slightest from the laudable character of such efforts, but considering our cosmic insignificance all such efforts must be recognized to be of but local and temporary importance.

But there are times when all of us find it a relief to think qualitatively rather than quantitatively. Archimedes, that pioneer mechanical engineer, is reputed to have said: "Give me a place where I may stand, and I will move the earth." The modern engineer does not even ask for a place to stand, for he knows that by merely shooting a bullet in an easterly direction he can (to a microscopic extent) play the part of Joshua and lengthen the day. Moreover, he knows that (still qualitatively speaking) he can perform actions whose results reach far beyond terrestrial limits. When he strikes a match to light his cigarette as he walks down the street, he knows that he has started light waves, some of which will travel outward and onward in space, perhaps forever.

With increasing knowledge of the universe our eyes have been opened, and we see that our actions may sometimes have a small measure of cosmic scope. It is inevitable that this should lead to speculation as to the possibility of broadening and increasing our cosmic reach. But here we leave the realm of fact and enter that of fancy. It is an attractive realm, as we all know, and by your leave I will tell you another story.

As I journeyed through the world I came to the shore of an ocean reaching far as the eye could see. The water of this ocean was colorless and transparent, and was ceaselessly in motion; even in parts where there were no breakers the water was continually moving in currents. And as I walked along the shore I noticed that there was no living thing in the water, not even a blade of sea-grass; nor did any living thing appear on the beach as far as I could see inland. Thus I wandered ever along the shore of the ocean, watching for some living thing, but finding none.

At length, after many miles of traveling, I came to a place where the sea ran inland, forming a little pool wherein the ceaseless currents played. By the side of this pool there lay an old man, gazing intently into the beautiful clear sea water, and my heart was glad at the sight of a living thing.

"Tell me, father," said I, "what is the name of this ocean? And what curse is laid upon it that there is no living thing in its waters?"

The old man looked at me for some moments without speaking. Then he said, apparently ignoring my first question:

"There are living things in it, but they are few."

"I have traveled many days," said I, "but I have seen none."

"When I was your age, my son," said the old man, "I traveled many months before I found them, and I have lain here watching them ever since."

I looked in the pool, and I saw amid the ceaseless water-currents a swarm of living things, hollow, clear-walled creatures, some like single bubbles, some like a heap of bubbles fused together; and the sea water within them was colored a beautiful rich tint which was new to me. I saw that in those creatures which were composed of many bubbles the color was deep, while in the simpler ones the color was paler, and in the single bubbles I could detect no color at all. I watched the creatures swimming about and pulsating rhythmically, and I said to the old man:

"They are beautiful! And are these the only living creatures in the ocean?"

He shook his head. "I do not know. The ocean is so vast—there may be others—but I have found none."

I looked again in the pool, and I saw that some of the creatures lay still, and

their color was paler than that of their fellows of like degree of complexity. The old man said: "They are sleeping." And I saw one creature which, from its complexity, should have had the deepest color of all, but it lay motionless and colorless; and the old man said: "It is dead."

I asked the old man: "What gives to the water within the living creatures its color? Do they secrete coloring matter?"

He answered: "I thought so when I first began to study them, but it is not so. Do you see the hairs that line their internal cavities?"

I looked, and I saw that the creatures had little hairs within, and that these hairs were constantly moving, beating and churning up the sea water within. The old man said: "When the sea water is beaten thus it suffers a subtle change and becomes colored."

And I said: "Why then is not the whole ocean colored, since it is ceaselessly beating upon its shore?"

The old man said: "I do not understand it; but it seems that it becomes colored only when it is stirred up by living creatures."

As I silently mused over this my ear caught the sound of a faint chirping. The old man said: "It is made by the creatures in the pool. The more complex ones are able to utter sounds, and the highest of all are even able to communicate with each other by this means."

"They talk!" said I. "Then they must think!"

"Ay, that they do," said the old man, "and strange and sad are some of their thoughts; for in the years that I have studied them I have come to understand a little of their language. For instance, this beautiful color is to them the very essence of the pleasure of their lives. The deeper colored pity the paler, and pity most of all those single bubbles which appear devoid of color."

"Are they really colorless?" said I, "or is their color only so pale as to be imperceptible?"

The old man bade me look again in the pool.

"Do you see," said he, "how the most complex and active creatures, having many hairs moving, are the deepest in color, and how those with fewer hairs to churn the water are paler? Are the single bubbles totally devoid of hairs?"

"No," said I, "they have a few, and these move slowly."

"What think you then? Are these devoid of color, or is it simply a question of degree?"

I felt that my question was answered.

"Ay," continued the old man, "it is a question of degree; for once or twice in the years that I have watched them I have seen single bubbles, under stress of great excitement, churn the water within them so vigorously with their few hairs that it assumed a pale tint."

Then I said, remembering how I had seen the sleeping ones and the dead one: "The depth of color in any creature seems to be proportional to its bodily activity; and among different creatures, to their complexity."

"Right," said the old man, "and this fact has been recognized by the most complex creatures themselves."

I said: "When the creatures sleep or die, and their color fades, what becomes of it? Is the change produced by beating the sea water so unstable that when the beating ceases the water reverts to its colorless condition?"

The old man looked grave. "So I thought at first, and many a sad hour have I passed thinking of the labor spent in producing this beautiful color, so unstable that it was doomed to perish with the ceasing of the labor that produced it. But," and here his face brightened, and he spoke with assurance, "it is not so. This change once produced is permanent; it can never be undone."

"But what then becomes of the color?"

He pointed to the pool, and I looked in. One of the most deeply colored creatures was just falling asleep. Slowly and still more slowly moved the hairs within it, and its color gradually faded. I watched closely, but I could not see where the color went. Then there came an instant when the ceaseless wash of the currents slackened, and in that instant I saw the water about the creature tinged with the beautiful color. I looked up at the old man.

"Ay," said he, "the color is permanent; but the colored water continually diffuses through the creature's body, waking or sleeping, and is dispersed and diluted in the vast ocean. When they sleep their motion is so far reduced that diffusion renders them pale; and when they die they become absolutely colorless. But the color does not die, the beautiful color—no, it can not."

"And do they know this?" said I, pointing to the pool. His face again became grave.

"I find that there is a great difference of opinion among the most complex of them. They all realize that it is this color that makes their lives worth living, and they recognize that its intensity is proportional to their bodily activity. They have an instinctive feeling that the color is permanent, but they are sorely puzzled to account for its fading during sleep and its disappearance at death; so that some say that this instinctive feeling of the permanence of the color is a delusion; that the color is really a most unstable thing, and that colored sea water can exist only within a living organism. This conclusion they sorrowfully accept and make the best of it. Others there are who refuse to accept it, and who cling to their instinct." And the old man sighed as he looked at the restless wash of the water in the pool. Presently he said:

"How long will it take, think you, until the whole ocean becomes of this beautiful color?"

I said: "If there be other creatures elsewhere, and many colonies of them—"

"Nay," said he, "I know not if there be such—I hope—but how long?"

I looked long and silently in the pool. Then I said:

"I see some creatures that are very pale; and they are not asleep, for they are moving about."

The old man's brow grew dark. "These are lazy ones," said he. "They have allowed themselves to become discouraged, and say: 'Why should we labor and beat our hairs to produce a color which must perish with us?' These are they that retard by just so much the coloring of the ocean."

"Nay, father," said I, "be not angry with them. It is but natural. Remember that they do not know."

"True," said he, and his face grew kind and pitiful. "They do not know."

Said I: "Suppose some great falling rock should crush these creatures out of existence?"

"But the color!" said the old man. "The color can not be crushed out of existence! And the ocean is so vast—there may be other colonies elsewhere; and even if there be none now, they may in time arise as this colony has done, I know not how. The ocean will be colored!"

I was silent a long time. Then I happened to think of my first question, which still remained unanswered.

"Tell me, father," said I, "what is the name of this ocean?"

"I have never heard but one name for it," said he, "and that is the name given it by these creatures themselves. 'Tis a strange name; there is no exact equivalent for it in our language. The nearest is Energy-of-the-Universe."

"And what do they call this beautiful color?"

"They are not agreed upon a single name. Some call it Consciousness, and some call it Soul."

BOOKS ON SCIENCE FOR LAYMEN

THE UNIVERSITY AND THE FUTURE OF AMERICA[1]

A SIGNIFICANT program was arranged to celebrate the fiftieth anniversary of the founding of Stanford University. Sixteen of America's busiest scholars who have contributed largely to the world's thinking accepted places on that program. Manuscripts of the addresses were assembled and edited by President Ray Lyman Wilbur under the above title. The theme selected for the celebration had been given to each speaker. Each one selected a theme for himself, which appears as his own chapter heading, but presumably each kept in mind the main theme of the entire program. However, that main theme was often quite eclipsed by the speaker's forceful and appropriate presentation of his own guiding stars which have led him in his preceding decades of work. That was inevitable, since thoughtful men usually are best when speaking of matters to which they have given prolonged and fundamental consideration. Even so, sixteen addresses, each masterful and distinct, may provide good foundation for study of the problems of "The University and the Future of America." Few of the speakers ventured into prophecy, mostly leaving what they said as sorts of known scaffolding extending off from the shore a little way, but not leaving the footing of secure land for less stable and turbulent areas of the open sea. The impossibility of writing a true review of this book does not constitute an adverse criticism. Had the book merely been scanned for general impressions, the preparation of this account would be less difficult.

In the first chapter, the reader follows President Isaiah Bowman in his almost poetic analysis of what people want, why and how they achieve it, his comment that usually people think "heaven is the absence of extreme heat or extreme cold; to others it is the absence of hunger, or sorrow, or night bombing." But to Bowman "heaven . . . is a state of social mind that tries to do something about the future, and looks around for means to ameliorate unnecessary hardship and to foretell a wise course of community action. . . . Science is manageable and swift in development largely because it is impersonal; atoms do not care. Social objectives . . . are the expression of a people's will, . . . when each man is thinking of his own good and only a few are thinking of the general good." But since it is the scientist who knows the atoms which "do not care," and since the scientist is surely a part of the social problem, he can not rightfully continue to escape his participation in its solving. Intelligent and educated people must all accept their personal part in society's problems. To laugh these off is stupid and suicidal. Bowman devotes much of his chapter to showing how his foundational conceptions might affect problems of conservation of natural, human and cultural resources. "We make a fundamental mistake if we suppose that we have either conquered nature or come to the end of our knowledge about her." But we must act every day though we often possess only part of the needed knowledge. Even democratic choices are often very unintelligent and badly willed. Eight guiding principles are developed and urged for adoption and use. These recognize the past, use the present and anticipate the future. Indeed one could with justice "define civilization today as an operating system of statistical services whose progenitors are found in the old Babylonian Kingdom. . . . statistics about the tools are almost as important as the tools." And the

[1] *The University and the Future of America.* Ray Lyman Wilbur and fifteen others. ix + 274 pp. $3.00. 1941. Stanford University Press.

future "is not all mystery. . . . the outcome is dependent upon our own intelligence, endurance, imagination, and will."

Professor E. O. Lawrence's chapter on "The New Frontiers in the Atom" is a cogent summary of atomic research as applied to the periphery of its area of present knowledge. To review the chapter would be to repeat much of it. Robert A. Millikan, great teacher that he is, turned his attention primarily to three fundamental needs in American education; selection of those who are competent to be educated in our present system, and rejection of the large numbers not competent; development of types of schools, shops and apprentice situations in which there may be trained the large numbers not competent to benefit by the present educational system; and citizenship education to the end that "at least fifty-one per cent. of the voters are capable of casting intelligent votes, and this requires a fairly broad education up to the age of seventeen or eighteen."

Roscoe Pound's chapter on "Education and Social Control through Law" justifies publishing the book. That certainly is true also of Edward Lee Thorndike's "Human Resources." Indeed, these two preeminent scholars have produced chapters which might well be required reading in their respective fields for every one who wants foundations for guidance regarding the objectives and means of human advance as well as clear limits on what is now known.

Education for Women (Aurelia Henry Reinhardt); Biological Basis of Human Nature (Herbert Spencer Jennings); Unified Approach to Knowledge and Life (Lewis Mumford); Science as a Liberal Education (Edwin P. Hubble); Medical Investigations (Walter B. Cannon); New Products (Charles F. Kettering); American Writers and the Future (Archibald MacLeish); The University and the Changing Society of the Future (William F. Ogburn); Economics, History, and the American University of the Future (Edwin F. Gay); and Résumé, by Herbert Hoover, complete the list.

Otis W. Caldwell

THE CHEMICAL CONTROL OF BACTERIA[1]

This is an ambitious little book designed to answer the most penetrating curiosity about the whole science of control of bacterial infection.

The first two chapters do an amazingly complete job of presenting in a nutshell both the theory and the practical aspects of infection and immunity. This is done with sufficient clarity to afford satisfying refresher material for physicians and others having some scientific background, yet so simply as to build a tangible picture for even the lay person.

The qualifying title of the book, "From Salvarsan to Sulphapyridine," justifies devotion of all beyond the first two chapters to chemotherapy. The early history of the development of drugs leads fascinatingly to the birth of organic chemical industry and the opening avenue to synthetic chemicals in medicine. Domagk's discovery of Prontosil introduces the remarkable new class of sulpha-drugs, the story of which is the real excuse for publication of this little volume.

In every step in his account, the author attempts to lay the scientific groundwork for a fairly sound background for the person who has had no training in science. This spadework for his presentation of synthetic organic chemistry is in some ways almost too detailed to be needed by any one with even high-school chemistry experience, yet in certain specific respects is too involved to mean much to any but those whose training already fits them for appreciating an unsimplified direct approach to chemo-

[1] *The Conquest of Bacteria.* F. Sherwood Taylor. Illustrated. 177 pp. $2.00. March, 1942. The Philosophical Library.

therapy. It would be only for these, for instance, that the justification of picturing atoms as hard spheres would be comprehensible. And the value in giving so much space to graphic organic formulae is easily open to question. To the person who is already familiar enough with chemistry, the author had undoubtedly made clear what is meant by "related drugs," hence what guide there is in the search for therapeutic chemicals. He has shown the difference between modifications which alter therapeutic properties and those which simply get around patent restrictions. He has given some notion of what is meant by "the peculiar atom pattern of quinine" which resists synthesis. He has emphasized the complex nature of all these compounds, therefore requiring expensive synthetic processes, trained chemists and the need for funds.

Not only is the last chapter devoted to a plea for public support of research, which Professor Sigerist commends in his foreword, but this point is made repeatedly in connection with each drug discussed.

The table of sulphonamide derivatives, with commercial names, is certainly revealing to the lay person and should be especially appreciated even by the average physician.

Some incidental features of the book deserve special commendation: The description of what it means to assay drugs will interest everybody. The reasons for not practicing self-medication are wisely included in a book for public instruction. The constant use of mortality statistics in illustrating the effectiveness of biological products and of drugs. The discussion of control of clinical tests and the paragraph on estimation of experimental validity are excellent. The discussion of "scientific method" of approach which high-school science teachers will appreciate for instructional purposes, and which will surely make "scientific thinking" more meaningful to the everyday readers.

There are many typographical errors that should be corrected before the next printing, but this comment on the careless proofreading is not intended to reflect on the general excellence of content.

J. Bronfenbrenner

ADVENTURES IN CALIFORNIA SCENERY[1]

American geologists have not been particularly successful in popularizing American geology; in fact, not many professional American geologists have attempted to make geology interesting to laymen. I. C. Russell's books on the rivers, lakes, glaciers and volcanoes of North America are shining exceptions, but they were published during the period from 1895–98 in a now outmoded format.

Mr. Willard's well-illustrated book is a popular account of California geology, part of which is written as an automobile guidebook. To geologists California geology is exciting, particularly on account of the crowded succession of events during late geologic time. It is not an easy task, however, to translate the events into a history appealing to laymen. Reed's "Geology of California" (1933), which is not included in the bibliography, and Reed and Hollister's "Structural Evolution of Southern California" (1936) summarize the work of California oil geologists, the results of which have revolutionized California geology during the last two decades. Both of these professional books might have been used to greater advantage in the preparation of "Adventures in Scenery." Reed's imaginative genius imparted to his accounts of geologic history an epic quality that would attract laymen.

W. P. Woodring

[1] *Adventures in Scenery;* A Popular Reader of California Geology. Daniel E. Willard. Illustrated. x + 438 pp. $3.75. 1942. Jaques Cattell Press.

A LAYMAN'S HISTORY OF THE THEORY OF RELATIVITY[1]

The author of this excellent little book sets for himself a double aim: to describe the historical development of scientific thought which prepared the ground for the formulation of the theory of relativity, and to analyze on this basis the fundamental physical principles and philosophical concepts of this theory.

The opening chapters of the book enroll before the reader's eyes the picture of the young physical science struggling through the difficult period of medieval history, and show how hard it was at that time to conceive and to spread about the ideas which look so natural and elementary to us to-day. The discussion shifts then to the more recent era, when the questions concerning the existence and the possible physical properties of the so-called world either came into prominence. This leads naturally to the famous experiment of Michelson which turned out to be a tombstone to all the mechanical views concerning the nature of light, and whose unexpected result represented at its time a real challenge to the scientific mind. The author relates farther how this challenge was taken up by Einstein, and how the attempt to interpret correctly this seemingly isolated physical experiment led to a deeply felt revolution in the entire field of physical science, causing scientists to change in a very fundamental way their customary views concerning space, time and motion. The chapters devoted to the more detailed discussion of the special and general theory of relativity are written in a very simple and easily understood way, and would give to a layman, only vaguely familiar with the facts and laws of modern physics, a very clear picture of "what it is all about."

This book can be readily recommended to everybody who wants to know what "the theory of relativity" is.

G. Gamow

[1] *From Copernicus to Einstein.* Hans Reichenbach. 123 pp. $2.00. 1942. Philosophical Library.

A YEAR BOOK OF PUBLIC HEALTH[1]

A retiring professor recently told me that his life had been a very happy one because he had new students each year learning from him things that were old to him but new to them, and that he himself had always new things to learn. Some of those trained in public health need to be reminded each year of the new things they must know, as well as the general field of public health, through which they must guide many others.

The 1941 Year Book of Public Health is a practical handbook that ranges from rape to Rocky Mountain fever and from encephalitis to fluorine. Dr. Geiger as editor has used his long experience as a health officer and teacher in making choices of the subjects to be dealt with and how much space each should be given. Air-raid casualties, evacuation ports, bombed water mains are certainly timely topics for doctors, public health workers, nurses and those citizens engaged in civilian defense work of all sorts.

The world-wide spread of diseases, especially from the tropical or subtropical areas, gets much less space than it will in the edition for 1942. Yellow fever and yaws get a hearing in the present edition suggestive of what will come in the years immediately ahead.

The book is a good and useful compendium that should find wide use in this time of direct concern of the whole public in health problems.

Ray Lyman Wilbur

[1] *The 1941 Year Book of Public Health.* J. C. Geiger, editor. Illustrated. 544 pp. $3.00. 1941. Year Book Publishers.

ROSS AIKEN GORTNER

THE PROGRESS OF SCIENCE

ROSS AIKEN GORTNER, 1885–1942

THE lamented death of Dr. Ross Aiken Gortner on September 30, at his home in St. Paul, Minnesota, removed from the ranks of American agricultural and biological chemists one of their most distinguished leaders. Gortner's work as investigator, teacher and author was so many-sided that there are few branches of applied biochemistry in which his influence is not felt.

Gortner was born at O'Neill, Nebraska, on March 20, 1885, and at the age of 17 entered the preparatory school of the Nebraska Wesleyan University at Lincoln, where he obtained his first instruction in elementary chemistry. Both here and in the associated university he made a brilliant record in chemistry under Professor F. J. Alway, who appointed him laboratory assistant and exerted a friendly influence on his career, not only then but later, in many ways. Evidences of this association are a number of joint publications on nitroso compounds, detection of bleached flour and studies on soils. After obtaining his B.S. degree at Nebraska Wesleyan in 1907, Gortner, on Professor Alway's advice, took a course in physical chemistry at the University of Toronto, where he earned his M.A. degree in 1908 under the late Professor W. Lash Miller for a thesis on "The Induction of Ferrous Salts of the Reaction between Chromic and Hydriodic Acids." For the completion of his academic training Gortner went next to Columbia University, where he obtained his Ph.D. degree in 1909 under Professor Marston T. Bogert, for an investigation in organic chemistry "On Some New Quinazoline Derivatives."

The years 1909–1914 were spent by Gortner as resident investigator in biochemistry at the Carnegie Station for Experimental Evolution at Cold Spring Harbor. It was during this formative period, when the foundations of his future scientific career were being laid, that Gortner's interest in biochemistry was aroused through a lasting friendship which he formed with the late Dr. J. Arthur Harris. In a beautiful tribute to this eminent botanist Gortner wrote in 1936:

> For more than twenty years I tried to absorb what I could of his philosophy of life and, sitting at the feet of a master, sought to learn from him how to integrate the random elements of natural science into a complete picture of the biological reactions of the living organism.

One result of this association with Harris was the collaboration by the two friends in an extensive research on the physico-chemical properties of vegetable saps, the results of which were published in some twenty papers.

In 1913 Dr. A. F. Woods, dean of the College of Agriculture of the University of Minnesota, invited Dr. F. J. Alway to join his faculty as professor of soil chemistry, and in 1914 Gortner was persuaded to become a member of his staff as associate professor of the same subject. This renewal of associations with his former teacher was a source of great satisfaction to Gortner as it afforded him a most favorable opportunity both for research and for realizing his cherished ambition of becoming a teacher of science. In 1916 he was made associate professor of agricultural biochemistry. His promotion to professor and to chief of the Division of Agricultural Biochemistry at the Minnesota Agricultural Experiment Station followed in 1917—a double field of activity which Gortner filled with distinction for the next twenty-five years.

Gortner's first biochemical researches, performed at Cold Spring Harbor, re-

lated principally to animal pigments, the chemistry of embryonic growth and the joint work with J. A. Harris on vegetable saps. His numerous investigations, conducted either singly or with students, at Minnesota comprised such topics as the organic matter of soils, the acid hydrolysis of proteins, sulfur in proteins, the state of water in colloidal and living systems, and applications of colloid chemistry in the study of flour and bread and in the investigation of plant and animal substances. In 1929 Gortner published his "Outlines of Biochemistry," of which a second edition appeared in 1938. This work met with a wide reception; eight well-worn copies in the library of the U. S. Department of Agriculture bear witness of its popularity and constant use among agricultural chemists.

The scientific recognition won by Gortner at Minnesota led to numerous requests for his services as lecturer at other institutions. He was the Wisconsin Alumni Foundation lecturer in 1930; the Priestley lecturer at Pennsylvania State College in 1934; and the George Fisher Baker lecturer at Cornell in 1935–36. His lectures at Cornell were published in 1937 under the title "Selected Topics in Colloid Chemistry." In 1936 Gortner with other colleagues at Minnesota prepared a memorial volume entitled "J. Arthur Harris—Botanist and Biometrician." It was through Gortner's influence that Harris in 1924 joined the faculty of the University of Minnesota where he was head of the Department of Botany until his death in 1930.

Although a biochemist of the first rank Gortner was never a narrow specialist and in his work as teacher, lecturer and writer the general relationships of biochemistry and other fields of endeavor were constantly stressed. His breadth of outlook is well illustrated in his address before the Pan-Pacific Food Conservation Congress at Honolulu in July, 1924, on "Agricultural Biochemistry and the Food Problem"; in his paper on "Biochemistry and the Problems of Organic Evolution," published in THE SCIENTIFIC MONTHLY for 1930; and in his article on "Biochemistry and the World Today" published in the *Sigma Xi Quarterly* for 1932. Gortner's range of scientific interests is also indicated by the numerous societies of which he was a member. He was a fellow of the American Association for the Advancement of Science; a member of the American Chemical Society (in which he held numerous offices as councilor, chairman of the biochemical and colloid divisions, associate editor, etc.), the American Society of Biological Chemists, the American Society of Naturalists (of which he was president in 1932), and the Society of Experimental Biology and Medicine. He was also a most active member of several honorary scientific societies, such as the chemical fraternity of Phi Lambda Upsilon (of which he was national president in 1921–26) and the Society of the Sigma Xi (of which he was national president at the time of his death).

In the devotion of time to advisory and committee work for the organizations of which he was a member, Gortner was always most generous. He was a member of the Willard Gibbs medal award and the Borden medal award juries of the American Chemical Society and as a member of the National Research Council was serving at his death on its committees for chemical and biochemical nomenclature, chemistry of proteins and colloid science. For his work in science Gortner was also the recipient of several honors. The honorary Sc.D. degree was conferred upon him by Lawrence College in 1932; he was elected a member of the National Academy of Sciences in 1935 and in May of the present

year he was awarded the Osborne Medal by the American Association of Cereal Chemists.

At the time of his death Dr. Gortner was engaged with his colleague Professor F. J. Alway on a comprehensive study of "The Sulfur Metabolism of Plants" under a grant awarded by a committee of the American Chemical Society in 1939 from the Herman Frasch Foundation for Chemical Research. Under the collaboration of the divisions of agricultural biochemistry and of soils at the Minnesota Agricultural Experiment Station considerable progress had been made upon this project which concerns the effect of sulfur-deficient soils on the growth and chemical composition of the crops grown thereon. Not only Gortner's associates but the entire world of agricultural science lament the irreparable loss which this and other incompleted investigations will suffer as a result of his untimely passing.

Colleagues and students all speak of the contagious love for science which Gortner imparted to every one with whom he came in contact whether in lecture room, laboratory or field. He radiated enthusiasm and his life was singularly rich in friendships, service and accomplishments.

The transmission of scientific influences from great teachers to their pupils was a subject that greatly interested Gortner in his later years. It was made the theme of his lecture on "Scientific Genealogy." The opinion of his friend Harris "that the teacher who lives in the lives of his students, and in their students in succeeding generations, provides a certain scientific immortality" finds its full expression in the life of Ross Aiken Gortner, for his memory is perpetuated not only in his published writings but in the work and careers of his many graduates.

CHARLES ALBERT BROWNE

THE NEW YORK MEETING OF THE ASSOCIATION

IN view of the fact that travel by railway and bus must now be reduced to a minimum, it is fortunate that the annual meeting of the American Association for the Advancement of Science is scheduled for New York City from December 28 to January 2, because about three thousand members of the association live in New York City and its immediate suburbs, and about ten thousand within three or four hours' ride by train.

New York City is a favorable place for holding scientific meetings because of its excellent educational and cultural institutions and the many colleges and universities that are near it. Within greater New York itself there are Columbia University, New York University, Hunter

American Museum of Natural History

SOUTH FAÇADE OF THE AMERICAN MUSEUM OF NATURAL HISTORY

THE MEETING PLACE OF THE SECTION ON GEOLOGY AND GEOGRAPHY AND THE SECTION ON ASTRONOMY.

College, the Rockefeller Institute for Medical Research, the great medical centers of Columbia and Cornell Universities, the New York Zoological Park, the New York Botanical Garden, the Brooklyn Botanical Garden, the American Museum of Natural History and a dozen other institutions of distinction. And not far distant are Cornell University, Princeton University, Rutgers University, Yale University, as well as several well-known colleges and many high-grade secondary schools. In addition to these centers of interest in science, there are several hundred industrial research laboratories in New York and its near vicinity, such as the Bell Telephone Laboratories and the laboratories of the Barrett Division of the Allied Chemical and Dye Corporation, the Fleischmann Company, Merck and Company, the Standard Oil Development Company, the Atlantic Coast Fisheries Company and the Hercules Powder Company. Nearly all the directors of these laboratories and a large percentage of their technical staffs are fellows or members of the association. Finally, there are thousands of men and women in the New York area who are greatly interested in the progress of science even though they are not professional scientists themselves. Many of these persons will desire to attend the general sessions at which distinguished scientists will deliver addresses, and some of them will be interested in the technical sessions of the various sections and of the more than thirty affiliated societies that will meet with the association.

In addition to the foregoing positive

PARK AVENUE ENTRANCE OF HUNTER COLLEGE, NEW YORK
HEADQUARTERS FOR THE BIOLOGICAL SCIENCES AT THE CHRISTMAS MEETINGS.

reasons why New York is a favorable place for holding a meeting of the association at the present time, there is a negative reason. It would be impossible now to hold a great convention in Washington or Pittsburgh or Detroit because of congestion due to the war. In New York, however, there are few great war industries, such as those that are seriously interfering with the normal life of other cities. It is confidently expected that adequate hotel accommodations will be readily available at reasonable rates for all who will attend the meeting.

But what about the meeting itself? Naturally many of its programs will be strongly colored by the war that now involves almost the whole world. Perhaps the most far-reaching of these programs is the symposium on "Science Teaching in War Time," a subject that derives its very great importance from the fact that sixty-three per cent. of the men now being inducted into the armed forces of the United States will be used in technical branches of the service requiring scientific preparation far beyond that which most of them have had. Since plans are under way for an army of over seven million men, the problem of giving them the necessary basic scientific training is far beyond the physical and personnel capacity of the Army. Hence the schools, from secondary schools to universities, must be called upon. It is because of the urgency of this work that Brigadier General Lewis B. Hershey, director of the Selective Service Training System, will leave his busy desk in Washington to appear as one of the four contributors to the symposium.

It is obvious that mathematics, physics and mechanics are essential for service in the Air Corps, the Signal Corps and the Navy, but what about such a subject as entomology? At first thought it appears to be a field that can be left uncultivated until after the close of the war. To assume that it is not now important would be an error. Perhaps its most obvious practical application is in the domain of public health because many serious diseases, such as malaria and yellow fever, are spread by insects. Within the past fifteen months the association has sold for the use of the Army and Navy about 2,000 copies of its symposium on human malaria, a large part of which is devoted to mosquitoes that transmit malaria and to methods of their control. But entomology is of great importance in quite different ways. For example, it is directly involved in the great problem of protecting growing food crops against insect pests. Acute scarcities of some of the important materials of which insecticides are made present a real threat to our food supply.

Among the subjects involved in problems of importance in prosecuting the war are botany in connection with rubber and food plants, geology as related to minerals, mathematics for artillery and navigation, psychology in questions of morale, engineering in industrial production, medicine in health of armed forces and civilians, agriculture for food, chemistry in the manufacture of products ranging from explosives to vitamins, and practically all the many other fields of science for which the association has sections or affiliated societies that present programs at its meetings. War and the pursuits of peace alike now hang on science. It colors philosophy and religion and all our ways of thinking; it makes interdependent the scholar and the denizen of the jungle. In fact, science has integrated the world, and it now remains for such organizations as the American Association for the Advancement of Science to serve as an efficient integrating agency for science to the advantage of both science and humanity.

F. R. Moulton,
Permanent Secretary

OLIN HALL OF CHEMICAL ENGINEERING AT CORNELL UNIVERSITY

Olin Hall of Chemical Engineering, given to Cornell University by Franklin W. Olin, was dedicated in October. It will house the specialized facilities required by the staff and students of the School of Chemical Engineering.

The building, as designed and equipped, reflects both the scope and the training procedure of the course in chemical engineering developed at Cornell under the leadership of Dr. Fred H. Rhoades, Johnson Professor of Industrial Chemistry and director of the School of Chemical Engineering. The curriculum, which leads to the degree of bachelor of chemical engineering, is ten semesters in length. This long period has appeared necessary in order to provide the necessary amount of training in basic chemistry and in plant engineering and then to integrate these into chemical engineering procedures.

As a student progresses in the course, he is required to exert an increasing degree of initiative and resourcefulness. To this end the fifth-year men are required to work on individual projects. Facilities to accommodate such projects take the form of unit laboratories, to each of which four men are assigned and in which the projects may be developed under the guidance of the instructor without disturbance by other students. The group in each unit laboratory is responsible for all that goes on in that laboratory. Each such room is equipped with laboratory desks and the customary supply of electricity, gas, water and air. Each laboratory is also provided with a hood, and there are available connections for drainage and exhaust from special apparatus that may be erected.

In further support of the program for the development of initiative and resourcefulness, there is provided a three-story unit operations laboratory, together with an auxiliary pipe shop, machine shop and wood shop, in which pilot plants may be designed and erected to test under operating conditions the

OLIN HALL OF CHEMICAL ENGINEERING AT CORNELL UNIVERSITY

PARTICIPANTS IN THE DEDICATION CEREMONIES OF OLIN HALL
Left to right: HOWARD E. BABCOCK, CHAIRMAN OF THE BOARD OF TRUSTEES OF CORNELL UNIVERSITY; JOHN OLIN, SON OF THE DONOR OF THE NEW BUILDING; PRESIDENT E. E. DAY; JOHN L. COLLYER, PRESIDENT OF THE B. F. GOODRICH COMPANY, WHO MADE THE PRINCIPAL ADDRESS; AND DEAN S. C. HOLLISTER OF THE COLLEGE OF ENGINEERING.

plant design developed under the student's project. The laboratory houses large pieces of equipment, such as evaporators, stills, absorption towers and filter presses, upon which the actual operation of pilot plants can be studied to secure accurate examples of performance of similar full-size plants for commercial manufacture. This laboratory also provides facilities for groups of students organized on the foreman-and-squad plan to run tests upon single pieces of specialized plant equipment.

Since Olin Hall is designed to accommodate 450 undergraduates and a proportionate number of graduate students, care has been taken to avoid congestion in the halls between classes. To this end, three of the four lecture rooms, a working library and reading room, three of the five recitation rooms, and the computation room have been placed on the first floor of the main wing, within easy reach of the main entrances. Eyestrain and other discomforts are avoided by constructing the lecture rooms without windows and furnishing artificial illumination at a uniform level. Temperature and ventilation are automatically controlled.

Special laboratories are well-equipped for work in chemical microscopy, metallurgy and metallography. Facilities are provided for the grinding and polishing of specimens. A wide range of equipment is provided for training the student in the necessary photographic techniques employed in these laboratories.

An important detail of construction is the use by the architects, Shreve, Lamb and Harmon, of cinder concrete block for all interior wall surfaces. These surfaces are then spray-painted to obtain the desired color. The effect of the porous texture of these blocks is to provide admirable acoustics throughout the building. Olin Hall is the first of the new group of buildings contemplated for the college of engineering at Cornell University. The entire project is laid out on the same functional basis as the design of Olin Hall.

S. C. HOLLISTER, *Dean*
COLLEGE OF ENGINEERING

THE POTOMAC RIVER IN FLOOD

On the twelfth of October, 1942, a tropical disturbance moved inland over the North Carolina Coast and dissipated.

A cyclonic circulation, established by this disturbance, persisted until the 17th, with its center over southeastern Virginia. The tropical disturbance carried with it a very deep current of moisture-laden air which extended over the headwaters of the Potomac River. A stagnant anticyclonic circulation over the northeastern United States helped to intensify the pressure gradient over northern Virginia so that persistent easterly winds were forced to rise and release very heavy rains over the windward slopes of the Appalachian Mountains. These rains combined with other convective showers, caused by lifting and convergence of the moist air brought in by the tropical disturbance, to produce a four-day period of record rainfall. Thus the stage was set for the highest flood of record in parts of the Potomac and Rappahannock River basins, the flood waters of the Potomac reaching its peak at Washington, D. C., on the morning of October 17.

The rains were heaviest during the fourteenth to the sixteenth and the maximum precipitations were recorded over the watershed of the Shenandoah River, which flows in a northerly direction to join the main Potomac River at Harpers Ferry, West Virginia, and in the headwaters of the Rappahannock River. Official records of the Weather Bureau indicate that more than 17 inches of rain fell in the vicinity of Front Royal, Virginia, and nearly 19 inches at Big Meadows, Virginia, during the storm period. An unofficial measurement of 27 inches was reported from a point a few miles north of Front Royal.

U. S. Army Photo

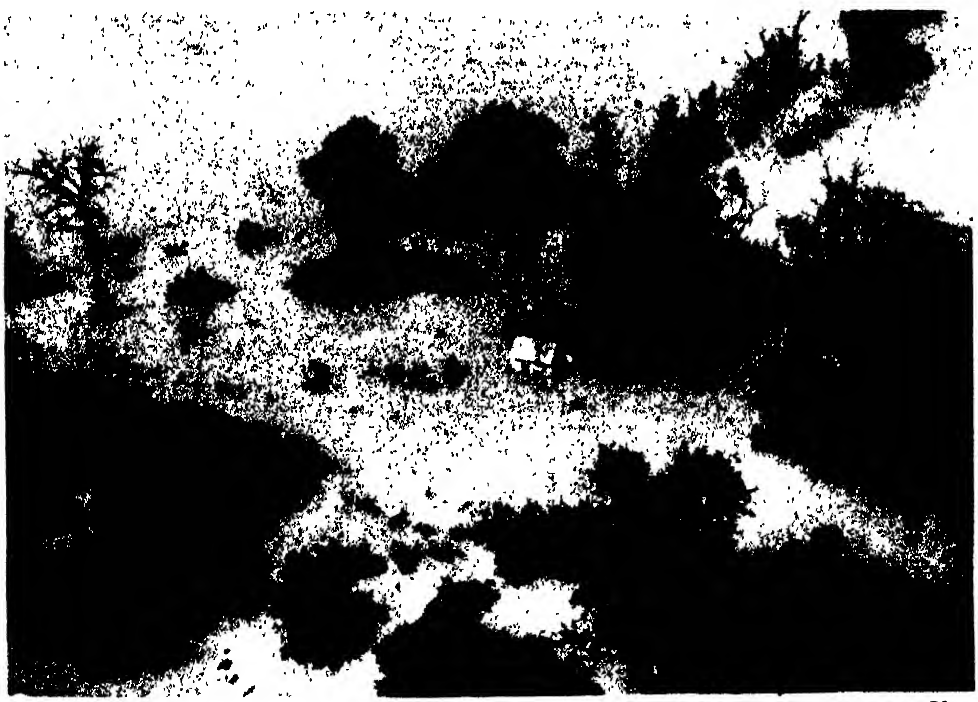
POTOMAC RIVER AT GREAT FALLS AT THE HEIGHT OF THE FLOOD

The highest stages ever known occurred in the Shenandoah River; at Riverton, Virginia, it is estimated that the river reached a peak of about 46 feet based on the Weather Bureau gage at that point. The waters were too high to allow the gage to be read at the time of the flood peak, but the elevation was determined from flood marks. In the great flood of March, 1936, a crest stage of 37.5 feet was reached on the Riverton gage.

In the history of Potomac River floods, during the period in which records are fairly well known, two floods have had prominence. These were the great floods of June, 1889, and March, 1936, and both were of about the same magnitude. In 1889 the flood in the Potomac was somewhat overshadowed by the much greater disaster at Johnstown, and in 1936 severe floods were even more wide-spread. Then record-breaking floods occurred in the Ohio River headwaters at Pittsburgh, in the Susquehanna River in Pennsylvania and New York, in the Connecticut and other rivers in New England, and in the James River at Richmond.

However, in 1942 the extremely heavy rains were almost entirely confined to northern Virginia, and except for the damaging flood in the Rappahannock River at Fredericksburg, Virginia, and neighboring points, the spotlight was turned on the Potomac and Shenandoah Rivers. The flood waters moved on Washington to produce a higher stage than had ever been recorded. The stage of 17.5 feet above Mean Low Water in the Georgetown channel at the foot of Wisconsin Avenue on October 17, 1942, was a third of a foot higher than the mark set in March, 1936.

Precautions to protect the city against floods had been taken even before 1936 and had been improved since then.



U. S. Army Photo

FLOOD SCENE IN POTOMAC VALLEY ABOVE WASHINGTON, D. C.

Washington Evening Star

A VIEW OF THE FLOODED STREETS OF BLADENSBURG, MARYLAND

These were mainly in the form of raised embankments and levees and improved channel conditions. However, with the greatly increased industrial and governmental establishments in Washington, with the need for temporary levees in certain instances and with the usual encroachment on the flood plains of rivers by peoples, it was necessary to warn residents and industries of this city and nearby towns that the Potomac River and its tributaries were to overflow their banks in the biggest flood since 1936.

Flood forecasting is founded on two of the older sciences, hydraulics and meteorology. Hydro-meteorologists of the U. S. Weather Bureau forecast river stages and flood crests by a series of computations in which the known quantities are the height of the stream farther up its course, precipitation in the watershed and the river's past performance. Gages at strategic points along the river and its tributaries provide the necessary information on river stages and a network of rainfall stations over the entire watershed furnishes the data on precipitation.

The river gages and the rainfall gages are usually read by a part-time Weather Bureau employe living nearby and the readings are reported by telephone or telegraph to the Weather Bureau office at regular intervals or when requested.

Gages are of several types. The two main classes are the recording and the non-recording. Non-recording river and rain gages are read by observers at designated intervals and these readings form the record. Recording gages automatically measure the rise and fall of the stream, or the fall of precipitation, on a continuous record sheet. The sheets are taken out from time to time by the observer.

Automatic river gages also are used in

Washington Evening Star

BARRICADING A STREET IN WASHINGTON AGAINST THE FLOOD

which the recording end at the river's edge measures the stream's rise and fall and transmits the record by leased telephone lines to the receiving end of the instrument in the Weather Bureau office some distance away.

Another type of automatic river gage which was used to great advantage in the present flood is a device whereby signals may be obtained from the gage by telephone indicating the stage of the river in feet and tenths or hundredths. The mechanism which transmits the signal is activated by a float attached to a tape. The float rises and falls with the level of the water in a stilling well corresponding to the stage of the river. The signals transmitted vary in sound or in time interval depending on the stage of the river. The gage house is called as in making an ordinary telephone call. As the telephone rings another automatic device raises the receiver and at the same time the signaling mechanism begins to operate and the signals are heard over the telephone.

Any type of gage is often damaged or put out of commission by severe floods. Even rain gages are sometimes flooded or washed out by high water. In the 1936 flood the automatic recording river gage at Washington failed to function. However, in the present flood, river stages were obtained by telephone, 24 hours of the day and as often as desired, from the gage in Washington and another located about 6 miles above the city. At the same time a pen in each of these gage houses traced out the continuous rise and fall of the stream on a record sheet.

BENNETT SWENSON

U. S. WEATHER BUREAU

GEOGRAPHY AND TOOTH DECAY

Because tooth decay is such a common disease, there is a general tendency to believe that all individuals and groups in the population are affected in much the same degree. There is considerable evidence to indicate that such a conclusion is inaccurate.

Significantly less tooth decay is found among groups who reside in certain geographic areas and, therefore, are exposed to specific environmental influences characteristic of these regions, than is found among other groups living under what are, apparently, much less favorable conditions. The record of physical examinations for military service outlines this situation.

During the last World War, data were collected from draftees which show a wide sectional difference in the rate per thousand of men rejected for "defective and deficient" teeth. It is true that diseases other than tooth decay would contribute to the conditions causing this type of "unfitness." Yet it is believed that among the particular age groups involved, the effects of dental diseases other than tooth decay upon the rates would be so minor that they may be disregarded. "Defective and deficient" teeth stood eighth among the thirty-seven items which were listed as leading to rejection for physical unfitness. Of men from the forty-eight states and the District of Columbia, the mean rate was 24.2 per thousand men examined. The distribution about this mean ranged between 2.90 for Arkansas and 102.85 for Vermont. The New England states, as a unit, outranked all others, while the states of the South and Southwest were consistently low on the scale.

In the Civil War, the condition described as "missing teeth" contributed significantly to physical unfitness among the men who were drafted from the northern states during 1863 and 1864. The rejection rate for dental defects, 20.49 per 1,000 examined, stood fourth in magnitude among the sixteen items listed as leading to rejection. It was noted at that time that there were marked differences between various states in the number of men rejected for this defect. The men of New England, when compared with those of the other states, were found to have the poorest teeth. Among the states contributing to the drafts of the two periods, there is striking agreement in the order in which the rates fall when listed according to magnitude.

Sufficient data from the present draft are not yet available to allow a reliable conclusion to be drawn regarding the current situation, but preliminary reports indicate there will be a comparable distribution of rejection for "deficient and defective" teeth.

The dental defects which cause men to be physically unsuited for military service are not likely to have started their development in the adult, but in the youth. Extensive surveys among children of school age indicate a relationship of caries attack to geographic location that is similar to that obtained from war records. For example, among boys having a mean age of 13, residing in cities of over 100,000 in Florida, Virginia and Massachusetts, the mean number of caries-attacked permanent teeth per child was found to be 3.1, 4.2 and 5.7, respectively. Similar differences have been noted among children of other states.

Bion R. East

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